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Modifications to the PED Model

Improved Housing and Population Forecasts
The Office Space Model

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I. PREFACE

A. PROJECTIONS OR FORECASTS ? - A QUICK HISTORY OF SEMANTICS

Prognostications of population and employment have been prepared at least since the nineteenth century (Pittenger, 1976). The first set of future estimates for the US government (total State populations up to 1960) was prepared for the National Resources Board by the Scripps Foundation for Research, in 1934 (Siegel, 1953). By the end of World War II, other government agencies, especially the Federal Power Commission and the US Office of Industry and Commerce were producing their own numbers. Projections for the Census Bureau were produced by the Scripps Foundation until 1950, when the Bureau began to prepare its own estimates.

Human events are not always predictable. For example, no one foresaw the post World War II Baby Boom, or for that matter the decline in fertility in the 1970's. Therefore, the glaring inaccuracy of the projections for Post War populations coincided with the time when many government agencies adopted the policies of both preparing future estimates and of utilizing such estimates in long range planning. Keyfitz, in the book The Politics of Numbers, describes how this problem was resolved.

"At that time someone came up with a distinction between projections and forecasts. The former consisted of a noncommittal working out of a set of stated assumptions and did not pretend to be an account of the future. That would protect the agency from blame for the inevitable errors.

"Users, on their part, continued to seize on any set of numbers labeled with future years. They reasoned that such numbers would not be published unless they were usable, and the assumptions selected by the Census Bureau or other office were taken (usually without examination) as representing a reasonable assessment of the future - why else would they be chosen? The devise by which numbers are called projections (and hence in principle hypothetical) could be put out by census offices and read and used by the public as though they were best possible forecasts seemed to cover all requirements: They protected the official agency at the time that they provided needed material. The fiction embodying this contradiction served a valuable purpose." (Keyfitz, 1976).

The terms 'projection' and 'forecast' are used interchangeably in this report.

II. SUMMARY

The New Jersey Department of Transportation (NJ DOT) utilizes several trip generation/trip distribution models to simulate future traffic conditions in the State. In general, these models are based on statistical relationships between residential locations, demographic characteristics, employment locations and travel related to work or other purposes, such as shopping. This type of modeling allows NJ DOT to anticipate road improvements that would be needed for future traffic. NJ DOT also uses modeling to plan public transit services and to predict future air quality conditions, as they relate to travel conditions.

To assist the Department with this work, the New Jersey Office of State Planning was asked to expand its Population and Employment Distribution (PED) model so that it could produce municipal scale forecasts of population, employment, income, household size and households by income group. The PED model assigns exogenous regional or county forecasts to municipalities based on historic growth patterns and land availability. To accomplish this task, several refinements were made to the model.

1. The method to make initial municipal assignments of houses and jobs was improved. An extensive literature search discovered that a combination of mathematical methods, based on the growth recorded during the previous 10 year period, would produce the most reliable initial estimate of municipal growth or decline. This methodology was incorporated into the PED.

2. The method to estimate municipal population was improved. The PED first converts regional population into an estimate of housing; assigns the housing to municipalities and then converts the municipal housing into an estimate of municipal population. This demographically robust method was improved by more careful accounting for seasonal housing; by the addition of alternative housing densities into the land fitting portion of the model; and, most importantly by new research which allows OSP to statistically convert municipal houses into municipal households by size and then to aggregate this forecast into total municipal population by adding the resultant municipal household population with the estimated municipal group housing population. This methodology begins the process of incorporating income and density (perhaps a surrogate for race and ethnicity) issues into the process of estimating municipal population.

3. The method to assign future employment was improved by the addition of alternative employment densities and most significantly by the development of an office space forecasting and fitting subroutine. OSP now is able to estimate the future demand for office space given the exogenous forecast of employment by type. This office demand is then fitted into existing office building before the model begins to assign growth to new land and buildings. Given the huge inventory of office vacant space that now exists in the State, this routine pre-assigns approximately 100,000 new jobs into existing space that is forecast to be remaining in the future thereby significantly altering the municipal forecasts of future jobs.

4. The model now includes a simulation of both the capacity based growth concept and the Resource Planning and Management Structure found in the State Development and

Redevelopment Plan. In this Plan simulation the model assumes that Plan modifies Trend growth by re-directing new trend growth from areas in a region without sewers (the surrogate for capacity based planning) to Centers located in the same region.

5. Other adjustments to the model include updating the model to base year 1990, the addition of alternative wage options and the addition of the COAH/Rutgers available land inventory to the model.

III.PROBLEM STATEMENT

A. BACKGROUND

The New Jersey Department of Transportation (NJ DOT) utilizes several trip generation/trip distribution models to simulate future traffic conditions in the State. In general, these models are based on statistical relationships between residential locations, demographic characteristics, employment locations and travel related to work or other purposes, such as shopping.

To develop these models, historic information from the US Census and/or from various types of surveys is aggregated into geographic areas called zones. Statistical methods then are used to establish relationships among the data and to develop equations which would be able to assign residents to destinations (work, shopping etc.) in a way that replicates the existing travel pattern. Once the equations are successful in replicating existing travel patterns, they are included in models used to project future conditions.

NJ DOT uses statistical modeling for several purposes. Modeling allows NJ DOT to anticipate road improvements that would be needed for future traffic. NJ DOT also uses the models to plan public transit services and to predict future air quality conditions, as they relate to travel conditions.

The Office of State Planning (OSP) has reviewed one of these models, the Northern New Jersey Regional Transportation Model[1]. In this model, Bergen, Essex, Hudson, Middlesex, Monmouth, Morris, Ocean, Passaic, Somerset, Sussex and Union counties were subdivided into 1216 traffic analysis zones (TAZ). Some of these zones were larger than municipal boundaries but many of the zones were subsets of municipalities. Trip generation was related to population and employment. The frequency of trips was related to household income, household size and the purpose of the trip (identified by type of employment at the trip's destination). The assignment of trips between zones utilized a form of the "gravity model" which posits that trip attraction is positively related to the attractions (the number of jobs) at the destination zone and inversely (negatively) related to the travel impedance between zones (the distance, the cost, and the difficulty in making the trip are viewed as forms of impedance). The model also estimated the trip mode (car, bus, rail, walk), the time of the day the trip will take place and the anticipated amount of truck traffic (much of which is simply passing through the model's region and is not generated in the region or going to destinations in the region).

At the present time, the Northern New Jersey Transportation Model requires that the following information be projected for each of the 1216 TAZ's that the model uses. In terms of the model’s data requirements, the Northern New Jersey model is representative of the other models used by NJ DOT.

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[1]Barton Aschman Associates et al. Northern New Jersey Regional Transportation Model Development Project, Travel Model Summary. March 1990, revised May 1990.

Table 1
MUNICIPAL FORECASTS REQUIRED BY THE NORTHERN NEW JERSEY TRANSPORTATION MODEL

population
households
median income (household)
households by size (six size categories from 1 person to 6+ persons)
households by nine income categories
total basic employees (SIC 1 through 51)
total retail employees (SIC 52 through 59)
total service employees (SIC 60 through 99)

Unfortunately, no agency produces all of the information at the traffic analysis zone level required by the model. The New Jersey Department of Labor prepares projections of population, employment and income for the State and its counties only. Private services such as Woods and Poole, DRI, WEFA and CUPR also make projections, but again these estimates are for the State or its counties. The Delaware Valley Regional Planning Commission projects municipal population and employment for the counties in its region, but does not project the remainder of the State nor does it project the income or household size information required by NJ DOT.

To provide the projection data required for its modeling efforts, NJ DOT hired the Regional Plan Association (RPA) and the New Jersey Office of State Planning (OSP) to produce municipal scale projections. RPA, through its consultant Urbanomics, was given the assignment to develop State and County scale projections of population and employment in five year intervals beginning in 1995 and ending in 2020. The Office of State Planning was contracted to use its existing Population and Employment Distribution (PED) model to distribute these State and County projections to municipal scale. The OSP projections would be utilized by the NJ DOT models by aggregating or disaggregating them to conform to TAZ boundaries.

B. DESCRIPTION OF THE PED MODEL

The Office of State Planning (OSP) Population and Employment Distribution (PED) model[2] assigns state-wide estimates of population (and employment) to municipalities. It was initially developed in 1988 - 1989 to allow the Office to measure the land-use, fiscal and infrastructural impacts of a variety of growth scenarios as the State Plan was being developed. In the period 1990 through 1992 the model was substantially revised to include subroutines that estimated future year municipal mean household income and the future year distribution of households into income groups[3]. This section describes the PED model as it existed at the beginning of the NJ DOT work program.

The model first converts future population into an estimate of future houses by projecting the number of persons who would head households (and by assuming that each future head of

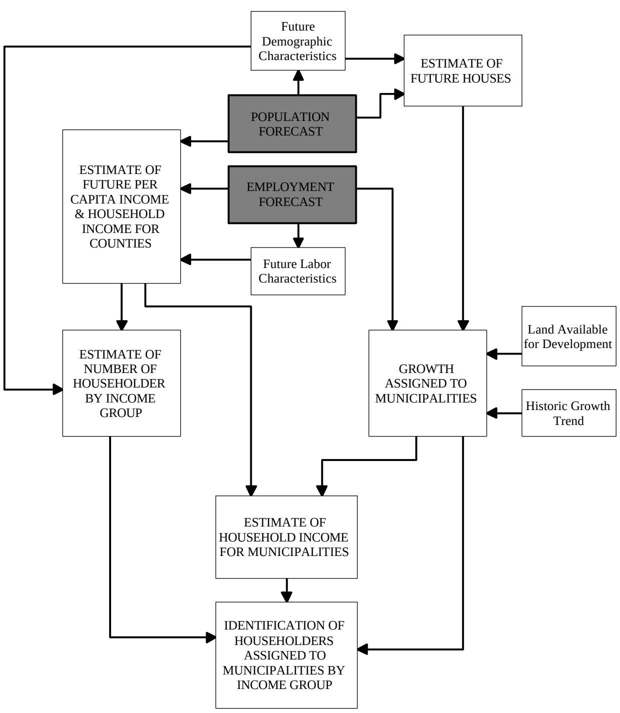
[2] See: Reilly, James and Gottlieb, Paul. Distributing Population and Employment Forecasts to Municipalities. Trenton: New Jersey Office of State Planning, 1990
[3] See: Reilly, James. Revisions to the PED Model: Analysis of Housing Need. Trenton: New Jersey Office of State Planning, 1993

household represents the need for a housing unit). To this need for household shelter is added an allowance for vacant units. The sum of total household shelter and total vacant units equals the total future housing units. The model then estimates the number of **new** housing units that would have to be constructed between the base year and the forecast year by subtracting residual housing units[4] from the sum of total future housing units. This estimate of new housing is performed at a regional scale; the region consisting of one or more counties. Finally, regional growth, both new housing that needs to be constructed and new employment, is assigned to municipalities using algorithms based on two assumptions:

1. Future municipal growth would be similar in magnitude to the growth that occurred during a specified, user-selected, historic period; and,
2. Growth can only be assigned to municipalities with sufficient land available to accommodate new development, and that any growth in excess of the municipality's land capacity must be reassigned to other municipalities with sufficient land[5].

The following diagram show the assignment process used in the PED as consisting of four main actions or steps. (It should be noted that the following describes a trend simulation, since a Plan simulation was not developed for this version of the model).

Diagram 1 - Schematic of the PED Model



1. $MH^{t+i} = MH^{t+i}(RH^{t+i}, TR, L^{t})$
2. $POP^{t+i} = POP^{t+i}(MH^{t+i})$
3. $Y^{t+i} = Y^{t+i}(DPOP, DEMP, Y^{t}, DENSITY^{t})$
4. $YGroups = YGroups(Y^{t+i})$

where:

MH^{t+i} = Houses in a municipality at time t+i
RH^{t+i} = total houses in a region at time t+i
L^{t} = land available for development at time t
TR = municipal trend growth rate
Y^{t} = municipal household income at time t
Y^{t+i} = municipal household income at time t+i
POP^{t+i} = Municipal population at time t+i
DPOP = Change in municipal population between time t and time t+i
DEMP = Change in municipal employment between time t and time t+i
DENSITY = Municipal density at time t
YGroups = Number of households in each income group

[4] Residual units consist of the total base year supply of housing units less an estimate of units likely to be demolished or otherwise lost, plus an adjustment for housing units created by converting non-residential structures to housing.
[5] A part of the OSP program calculated redeveloped land that could be made available in urbanized areas.

1. Step 1 - Assign Growth to Municipalities

Housing need is estimated from the population forecast, using a modified "Headship" method. An estimate of future population living in group housing (as distinguished from households) is subtracted from the total population estimate, to identify the future household population. This household population forecast for each county is further specified into the number of persons in each of 88 age, race and sex differentiated cohorts. The total householders in each adult cohort then is multiplied by a "headship" factor, which represents the percentage of persons in the cohort likely to head their own household at the forecast year. The model contains several headship rate tables, each embodying different assumptions about household formation tendencies. The model prompts the user to select a headship rate alternative. The result is an estimate of the number of persons who head households in each county at the forecast year. It is assumed that the total "headed" households is equal to the total number of households, and that each household represents a housing shelter need.

Total future housing units are estimated by adding a vacancy factor to the total housing shelter need. The model allows the user to select a vacancy factor which ranges for a low of zero to a high of 10% of the total future housing stock.

The next portion of the program estimates the number of future total housing units that will be newly constructed between the model's base year of 1986 and the forecast year. The total 1986 existing housing stock is used as the base to determine residual housing, defined as the number of today's housing units remaining in the forecast year. First, the model user determines the number of 1986 housing units that would be demolished, burnt or otherwise lost, by selecting from several demolition alternatives contained in the PED model. Next the user decides the number of non-residential units that will have been converted into housing use; again by selecting from conversion alternatives contained in the PED model. Residual housing is determined by subtracting demolitions from the 1986 housing stock base and then adding to the remainder the total units converted[6]. The total number of new housing units constructed between the base year and the forecast year is equal to the difference between the total future housing units and the total residual housing units.

New housing units and new jobs (the difference between base year employment and the projected employment) are assigned to municipalities based upon each municipality's trend growth rate and supply of available vacant land. The supply of vacant developable land in each municipality was determined for the base year 1986 through interpretation of 1: 24,000 aerial photographs, performed by OSP[7]. The density used to assign houses and jobs also was derived from this photo analysis. OSP measured the total developed land in each municipality. Using municipal based employment estimates (based on ES 202 data) and industry specific estimates of

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[6]Failure to adjust the base year housing supply for demolition and conversions can result in substantial errors. OSP calculated its demolition and conversion tables from several sources, including the Census and NJDOL-collected building permits. Based on these sources, the annual changes to the state's housing stock range from almost -3000 units a year to a high of about -12,500 units a year.

[7]New Jersey Office of State Planning. Estimating Growth and its Effects, part1: Land Availability Analysis. Trenton: Office of State Planning, 1989.

land per employee, land used by non-agricultural employment was estimated and subtracted from each municipality's estimate of developed land. The resulting non-industrial developed land residual then was divided by the total housing units in the municipality to yield Trend residential density per non-industrial acre. From this methodology a specific employment and housing density was used for each of the State's 567 municipalities. The program also allows the user to alter this 1986 estimated density by as much as plus (denser) or minus (less dense) 15% to fit future housing.

Future municipal growth is initially estimated to be an identical portion of the forecasted regional growth as the municipality's rate of regional growth was during a user selected historic period. (If the municipality's growth represented 10% of the regional growth in the base period, then the forecasted growth would be 10% of the regional forecasted growth). Model user's can select any decenial period or combination of 10 year Census year periods from 1950 through 1980. This trend growth rate is expressed as a percentage of a region's growth share, the region consisting of one or more counties.

Then each municipality's share of the forecasted regional growth (houses and jobs) is tested to see if sufficient developable land is available in the municipality. The testing is performed by multiplying the municipality's share of regional growth by the municipal-specific residential or employment density and comparing this result to the municipal supply of developable land. If sufficient municipal land exists, then the regional growth share is assigned to the municipality. If insufficient land exists, the growth that can be accommodated is fitted and the remainder reassigned to other municipalities in the region.

2. Step 2 - Convert Municipal Housing Assignments to Population Estimates

Municipal households are converted into municipal estimates of householders by multiplying the number of households by a county specific factor. This factor is derived by dividing the county's total forecast year household population by the county's total forecast year housing units. To this municipal scale estimate of householders is added the municipality's estimates of residents who live in group housing (1980 group quarters population). The model uses the 1980 Census enumerated group housing data as a constant[8].

3. Step 3 - Estimate Forecast Year Municipal Income

Two subroutines are used to estimate forecast year municipal income. First, Per Capita income, Group Housing income and Household income for each county are estimated using an OSP developed series of equations, based on the United States Department of Commerce, Bureau of Economic Analysis' OBERS model. This model takes forecast year projections of employment and population and estimates state and county future incomes from this data. The second subroutine estimates forecast year municipal incomes based on municipal changes in population and employment, the density of the municipality and the base year per capita income of the

[8]The limitation of this method is recognized, especially in light of the 1990 Census report that group housing in New Jersey increased by almost 50%. OSP has identified the need to develop a more sophisticated method to estimate future group housing needs.

municipality. The main equations used in this subroutine were developed by the New Jersey Office of Economic Policy[9]. The PED model then adjusts the municipal income estimates so the they sum to the county income estimates produced by the OBERS-like model.

The OSP-OBERS model first estimates forecast year county personal income by separately estimating money income from earnings, property and proprietary income and transfer payments.

The exogenous employment forecast (selected by the model user in step 1) provides county specific projections of forecast year employment for each of the ten general types of industries (two digit SIC's). The employment then is multiplied by county specific estimates of future wages for each of these types of industries. The result is an estimate of future county specific earnings for all jobs located in each county. From this county job-located earning estimate, projected Social Security is deducted. Finally, county residential earnings are estimated based on statistically based adjustments to the historic county-specific ratio between residential earning and job-located earnings.

Property and proprietary income is assumed to be a fixed percentage (22%)[10] of county residential earning. The three types of transfer payments, Social Security income, pension income and public assistance, are separately calculated. Social Security is assumed to equal a fixed percentage (.043)[11] of residential earnings. Pension income was calculated by multiplying the county specific number of persons aged 65+ by an income factor, based on estimated future total county estimated personal income. The total public assistance payment was calculated by multiplying a per capita payment by the number of forecast year persons in a population cohort, statistically related to welfare payments.

The sum of all these county specific incomes equals total forecast year personal income for the county. Average future per capita income is determined by dividing the total personal income by the county's forecast year population. Forecast year total group housing income and total household incomes were estimated by assuming the existing (1980) ratio between group housing income and household income would remain constant. Forecast year average household income was derived by dividing total future household income by the forecasted number of household, determined in step 1. Average forecast year household incomes for the State and for each county were calculated.

The New Jersey Office of Economic Policy (OEP) model calculates mean municipal per capita income, based on statistical relationships between changes in municipal population and employment, the base year municipal density and the base year municipal per capita income. Changes in municipal population and employment, produced by step 1 of the PED model, were input to this econometric equation. However, the model's results were adjusted so that the sum of OEP model's municipal per capita incomes was equal to the total future per capita income

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[9] You, Jong Keun. "Understanding Uneven Regional Growth". 19th Annual Report of the Economic Policy council and Office of Economic Policy. Trenton: Office of Economic Policy, 1987, pp. 1-31.
[10]This assumption is the same used by BEA in the OBERS model.
[11]IBID.

estimated by the OSP OBERS-like model. This adjustment was necessary because the OBERS-like model is sensitive to sectorial changes in employment while the OEP model is not. The adjusted average municipal per capita income was used to estimate both total municipal group housing income and total municipal household income. Finally, mean forecast year municipal household income was calculated using the future number of municipal specific households produced in step 1 of the PED model.

4. Step 4 - Estimate the Distribution of Income Groups in Each Municipality

The method to estimate the distribution of household income groups involves three main steps. First, the forecast year households, grouped into age-race (of head of household) cohorts, are multiplied by incomeship[12] factors to identify the number of households in each of the eight income groups in each county. .

Second, forecast year mean household incomes for each of the eight income groups are estimated. The forecast year State mean household income is multiplied by eight factors, each expressing the 1980 household income group's mid-point value divided by the 1980 mean state household income. For each county, the resulting estimate of the mid-point for each of the State's income groups then is adjusted so that the sum of each county's total number of households in each income group times the adjusted mid-point income for each group is equal to the total household income for the county, as estimated in step 3.

Finally, the number of households in each municipality in each income group is estimated. The sectoring equations are applied to the mean municipal household income, estimated in Step 3. The resulting "raw" estimates then are adjusted to ensure that county and municipal mean household incomes can be derived. In addition, the county estimates of the total number of households in each income group are used to adjust sectoring equation-based estimates of the number of households in each income group in each municipality. Surprisingly, these "consistency" adjustments result in very small changes to the "raw" sectoring results.

C. DEFINITION OF THE OSP WORK SCOPE

OSP was contracted to produce municipal forecasts for use in the NJ DOT trip generation models. To accomplish this task it was necessary to make substantial adjustments to the PED model and to add new subroutines to the model. The work scope accomplished under this contract was initially defined in December 1992 and work was begun on the project. The preliminary results of this work effort were reviewed in April 1993 by NJ DOT officials and by two expert panels conveined by NJ DOT. (The one panel consisted of agencies that prepare projections and the second panel consisted of agencies that use projections). In response to this review, further work items were added. The following is a list of the revisions to the PED model that were undertaken during the course of this project. Ultimately, the work accomplished by OSP

[12] Incomeship factors are similar to headship rate factors; except they represent the percentage of household heads organized by age, race and sex, represented in each of eight income groups.

produced all of the required input data needed by NJ DOT except for estimates of municipal employment by type.

a. Improved initial assignment of houses and jobs to municipalities.

b. Improved municipal population forecasts.

c. Improved municipal employment forecasts.

d. Development of a Plan (State Development and Redevelopment Plan) scenario.

e. Other adjustments to the model
i. 1990 base year for data and statistical equations
ii. Additions of the model’s inventory of available land.
iii. Definition of alternative future wages.

IV. REVISIONS TO THE PED MODEL

A. IMPROVED INITIAL ASSIGNMENTS

The initial assignment of houses and jobs to municipalities assumed that whatever growth rate occurred in a municipality during the user selected base period would continue to the forecast year. (The fit of this initial assignment then is compared to the municipal supply of available land in the next portion of the model). While this assignment method seems straightforward, there were two unsupported assumption. First, OSP assumed that the use of any base period would produce forecasts just as reliable as any other base period. Second, the use of a regional share initial assignment method was arbitrary, and not based on any evidence of the superiority of this method. Therefore, the purpose of this first task was to learn if any forecasting method had been demonstrated to produce more reliable projections by conducting a comprehensive literature survey of research articles and books.

OSP researchers identified forty one (41) articles or books that were relevant to the issue of making small area projections. In collecting these works, the New Jersey State Library and the library at Rutgers University were visited[13]. A complete list of the articles and books can be found in Appendix A.

1. Model Types

The academic literature has developed three general ways to categorize the multiplicity of methods to project future populations or other variables. Methods can be grouped according to their *function, the nature of their assumptions,* or, the *technique* used to make the projections.

Functional projections are categorized by their usefulness to project either total populations, or to forecast the distribution of populations to smaller areas. The section about 'validity testing' discusses the reliability of the different projection techniques to make small area projections.

Methods can be grouped according to the *nature of their assumptions*; either extrapolative or judgmental (Pittenger, 1980). This distinction can be very academic (perhaps bureaucratic, as in the difference between projection and forecast). For example, if one projects population using a mathematical method it is not clear if this represents an attempt to extrapolate historic trends or if it represents a judgment that conditions will not change. It could be argued that all projections rely on judgments made by the modeler.

Methods also can be grouped by categorizing the *technique* used to produce the projection. The following lists the types of projection methods categorized by projection technique.

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[13]OSP researchers tried to use Firestone Library at Princeton University, but were informed that the use of this library required a fee payment.

a) Mathematics Trending or Graph Fitting

Trend models assume that whatever events affected past growth will continue to affect growth in the future. The differing equations represent different opinions of how best to continue historic patterns into the future. The Gompertz and logistic methods also assume that trend growth will continue, but these methods establish upper limits on change and slow growth as it approaches capacity. The following equations are typical of those associated with each technique.

Arithmetic change

$$P_t \bullet P_l \bullet {}^{x}\!/\!_{y}(P_l \bullet P_b)$$

Geometric /exponential change

$$P_t \bullet P_l \exp(rx)$$

Polynomial change

$$y \bullet a \bullet bx \bullet cx^2 \bullet dx^3 \bullet \ldots \bullet mx^n$$

Gompertz Curve fitting

$$y \bullet ka^{b^x}$$

Logistic Curve fitting

$$\frac{1}{y} \bullet k \bullet ab^x$$

Modified exponential

$$y \bullet k \bullet ab^x$$

b) Cohort Component

This method uses assumptions about future births, deaths and population migrations to project a segment of the population, called a cohort. In general, cohorts are identified by some combination of age, race and sex characteristics. The sum of all cohort projections then equals the total change in the population. The following equation shows the five year (1985) effect of death rate and migration assumptions on a 1980 cohort, and is typical of the type of equation found in cohort component models.

$$P_{85}^{a\bullet 5} \bullet (1 \bullet m)(1 \bullet d)P_{80}^{a}$$

c) Economic Demographic

This method uses statistical relationships between economic development and population to project future changes. For example, the OSP Income sub-routine uses an equation linking municipal density and changes in municipal population and employment to revise base year Per Capita Income (PCI) to horizon year PCI. A variety of regression methods are used to establish statistical relationships and the resulting equations used in the modeling. These include: simple regression; multiple regression; logistic regression; nonlinear regression; and auto regression.

d) Ratio Methods

All ratio methods assume that municipal growth can best be projected as a share or portion of regional growth. The following methods demonstrate alternative ways to define this relationship.

Shift-share (also called ratio trend) - logarithmic definition of regional growth rate applied to new growth in the region.

Census (1952) ratio method (shift share) - a local place is defined as a percent of a region for a given known period. The future population of the place is equal to the historic ratio (for the place) times the *total region's projected population*.

Apportionment - assignment based on a place's historic share of regional growth *applied only to the new growth projected for the region.*

e) Land Use Methods

Land use methods allow the use of any of the preceding techniques. They limit total growth (much like the Gompertz of logistic curves) by establishing capacities based on some theory of land use. The following two examples demonstrate this technique.

Newling method - densities are assigned to different places (municipalities are identified as being rural, suburban or urban; each with an assigned maximum density) and growth assigned until the density capacity is reached.

Dispersion method - regional population is assigned according to a gradient which postulates the densest population in urban areas (highest growth assigned) and the least population density in those areas farthest from the urban centers (least new growth assigned).

2. Validity Testing

While it is easy to identify the failures of past projections, such as the failure to accurately project Post World War II populations, and it is sometimes popular to dismiss all attempts at modeling the future as bad science, the truth is that some forecasts are reasonably accurate and some are not. To understand this phenomenon, and to identify methods to improve forecast reliability, many articles have been published which evaluate alternative forecasting methods. In general, these articles come in two flavors: academic critics and empirical tests.

a) Academic Evaluations

The general thrust of an academic evaluation is that a model's validity can be assessed by determining its ability to identify the underlying causes of a population change. For example, the cohort component method might be viewed as a valid technique because it identifies population change as a function of differing social practices, such as having more or less children or an increase in the tendency for adults to live in non traditional household relationships. Similarly, a linear projection method might be dismissed because it does not rely on explanatory variables. While such a criticism might be made by a social scientist intent on the process of learning about demographic change by building models, this type of criticism confuses a model's explanatory variables and equations with the analysis of the accuracy of the model's projections.

b) Empirical Evaluations

Siegel (1953) reported both the "reliability" testing then recently completed at the Bureau of Census and some earlier validity tests conducted in the 1920's and 1930's. Since that time, other related studies (Siegel, 1972; Greenberg, 1972; Isserman, 1977; Smith, 1987; Smith & Sincich, 1988; Smith & Sincich, 1990; Smith & Sincich, 1991) have been performed, principally testing the ability of alternative models to project population in a county or other type of political subdivision. The work of Murdock (Murdock et al., 1984) also tests population projections, but it does so for economic-demographic models. The findings of all of these reports are very similar.

• Model complexity does not improve model accuracy. The projections produced by mathematical trending, cohort component, ratio and economic demographic methods tend to produce the same degree of error[14]. Land use methods produce the least reliable projections.

• Forecast accuracy is a function of the forecast period. Forecasts over a shorter period were substantially more reliable than were forecasts for a longer period. For example, Smith and Sincich (1988, page 463) reported that the mean absolute percentage of error (MAPE) "for the 10-year projections were between 7.0 percent and 8.5 percent for all five techniques[15], whereas the 20-year projection displayed a wider range of 13.0 to 19.1 percent." In 1953, Siegel reported an error of 6.3 percent for a five year projection and an error of 33.8 percent in a thirty year forecast (Smith, 1953). In general, an overall error of about 10% appears to be a common finding for most projections made over a 10 year horizon. Smith (1991) finally reports that "in most instances there is a linear or nearly linear relationship between forecast accuracy and the length of the forecast horizon".

• Forecast accuracy is a function of the base period used to drive the projection. There are three issues related to this finding. First, projections based on growth during an unusual period

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[14]This observation applies only to small area forecasting. Beaumont and Isserman (1989) note that use of extrapolative methods to project large area population would likely produce a high number of large errors. The authors suggest that the continued use of economic demographic models for large area modeling should be continued until better methods are documented.

[15]The five methods used in the Smith report were: linear extrapolation; exponential extrapolation; shift-share; share of growth; and a simple average of the projections produced by the four other techniques.

likely will yield unreliable results. For example, it has been demonstrated that using the decade 1910 to 1920 as the base period to project subsequent years produces poor results (Smith & Sincich, 1990)[16]. Equally poor results would be produced by using the years of the Great Depression to forecast economic growth. Second, most researchers reported poor forecast reliability for places that have undergone rapid growth or decline during the base period. Researcher report that periods of very rapid change usually are unsustainable for more than one decade. Isserman (1987) suggested that forecast reliability would be increased by "dampening" vigorous growth or decline rates by using a double logarithmic method to project for places that have rapidly declined and by using an exponential extrapolation method to project for places that have rapidly grown. Third, Smith and Sincich (1990) tested various combinations of base years to see if use of a longer base period might moderate projections into being more reliable. They found that " increasing the length of the base period up to 10 years improves forecast accuracy, but that further increases generally have little additional effect. The only exception to this finding is long-range forecasts of rapidly growing states, in which a longer base period substantially improves forecast accuracy for two of the forecasting methods[17]."(Smith & Sincich, 1990, page 367)

• Forecast accuracy is a function of the size of the existing population of the place being forecast. Several researchers (Siegel, 1953; Isserman, 1977; Stoto, 1983; Smith, 1987, 1990; Murdock et al., 1984) have noted particular problems with projections for places with small populations. Smith (1987, page 993) observes that both his own research and the published results of other researchers have noted " a strong negative relationship between size of place and size of error; the larger the place, the smaller the error. MAPEs[18] were about twice as large for counties with fewer than 5,000 population than for counties with 100,000 population. ... This relationship becomes fairly weak for counties with 25,000 or more, however."

• Shorter Term Projections might be improved by interviewing local officials. Pittenger (1980) and Isserman (1993) argue that interviews with local development officials might be a productive way to identify more reliable growth rates for places that have rapidly changed or that might undergo rapid change. However, these observations are not documented.

3. Applicability of the Research to THE OSP PED Model

a) Population Projection Recommendations

Technique - On the basis of the research discussed above, the initial shift share equations used to distribute population and employment in the OSP PED model have been changed so that most assignments are made using an exponential formula as recommended by Isserman (1977) and Smith (1987). (However, in the PED model this methodology is not used to forecast municipal population, but rather is used to forecast municipal housing. The advantages to this conversion are explained in the next section).

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[16]The reason for those poor results was the distorting effect of large scale immigration allowed in the period 1910 to 1920, but substantially curtailed after 1920 with the adoption of Federal Immigration Laws.

[17]The two techniques were exponential and shift share, where the state is expressed as a percentage of the national population. Both methods reduced MAPEs in states growing by more than 25%.

[18]Mean Absolute Percentage of Error.

In places that have undergone either decline or substantial growth during the base period other formula are used. The recommendations of Smith (1988) and Isserman (1977) regarding mathematical trending for places with high base period rates of growth (use an arithmetic method) and decline (use a double logarithmic exponential method) have been incorporated into the OSP PED model's initial allocation sub-routine.

Finally, the program has been restructured to use the base period decade (1980 to 1990) as a program default. This incorporates the finding that the use of a decade increases forecast accuracy. If the program user feels that future events will more closely match another decade, the program allows the user to use their preferred period.

The resulting Boolean equation incorporates all three types of equations to produce the initial (pre-land fitting) forecast. The following example shows the equation used to project total new municipal houses in the forecast year. A similar equation is used to initially asisgn employment.

$$if\,(hrate > 0.1, hu90\left(\frac{years}{10}\right) \times (hu90 - hu80), hrate < -0.15, hu90 \times \exp\left(\frac{\log(hu90) - \log(hu80)}{\frac{\log(hu80}{10}}\right) \times years, hu90 \times \exp\left(hrate\left(\frac{years}{10}\right)\right)$$

where:

hrate = rate of change of municipal housing between the beginning and the end of the base period (1980 to 1990).
hu90 = number of 1990 municipal housing units
hu80 = number of 1980 municipal housing units
years = number of years being forecasted

The effect of these changes was tested by using the period 1970 to 1980 to project 1990 population and employment using both the shift share method originally in the model and the new equation. With the changes, the OSP model's projections were within the 10% MAPE reported in the research literature. Using the shift share method the error was closer to 18%[19].

b) Local Interviews

The final improvement to the OSP model is intended to mitigate errors concerning places that will begin to rapidly grow in the forecast period. As recommended by Pittenger (1980) and Isserman (1993), OSP and Urbanomics interviewed knowledgeable County and local official throughout the State to learn of growth "in the pipeline" as part of the current project. Given the three to five year horizon generally used by small to moderate sized developers and the banks that finance these developers, it is most likely, however, that this "pipeline" information will be helpful for projections up to the year 2000.

[19]The magnitude of this error is not as significant as it might seem for places that grew. After the initial allocation is made in the OSP model, the growth is modified if sufficient land is not available. However, the error is uncorrected for places that have lost population.

c) Traffic Zone Projections

Forecast accuracy can be improved if traffic analysis zones have base year (1990) populations of at least 25,000 persons and if the TAZs were made coincident with boundaries that generally are used by demographic and economic researchers[20]. Use of such traffic zones would allow for internecine estimates to be readily evaluated and the data added to the model at little cost to NJ DOT. Where municipal boundaries are not desirable (such as the designation of a CBD as a traffic zone, separate and distinct from the remainder of a municipality) demographic and land availability information need to be complied for the zone by aggregating tract level information. With this information, the OSP model can be expanded to produce projections for these sub-municipal areas and can be expected to produce reliable projections within the state-of-the-art levels identified in this report.

B. IMPROVED POPULATION FORECASTS

The PED model does not directly assign population. The model first converts the county or regional population forecast into an estimate of new housing that needs to be constructed. The model then assigns this new housing to municipalities, based on the municipality's growth rate during the period 1980 to 1990 (as described in the preceding section) and on knowledge of the municipal supply of available land. Once the municipal assignment of housing is completed, the model then converts the total future municipal housing back into an estimate of people. This conversion process has three main advantages:

- first, it allows the model to incorporate substantial demographic robustness thereby minimizing problems that could result from recent demographic trends to smaller household sizes and more non-traditional households;
- second, it allows the model to use the initial assingment formulas discussed in the preceeding section (Household population and houses are very highly intercorrelated); and,
- third, the conversion process allows the model to test for sufficient land to accommodate new growth.

Despite the robustness of the population assignment method and its improved ability to make initial "unfitted" projections, several shortcomings of the program were identified and four types of improvements made during the course of this work effort:

- Accounting for seasonal housing;
- Revisions to the housing need equation;
- Housing density alternatives; and,
- Better methods to convert houses back to municipal population forecasts.

[20]OSP requested that NJ DOT provide maps of the Northern New Jersey Transportation zones, overlaid on a base map showing municipal and Census tract boundaries. This map was not supplied to OSP.

1. Seasonal Housing

As previously stated, the model converts forecasted population into an estimate of forecasted new housing. In making this housing forecast, the model assumed that base year housing stock, that was not demolished or vacant, would be available to house future households. While this assumption generally produces satisfactory estimates of housing need; it produced unsatisfactory housing need estimates in municipalities with large numbers of seasonal houses. This problem was particularly acute in the counties of Cape May, Ocean, Atlantic and Monmouth, where large numbers of vacation houses have been constructed. For example, in Cape May county 42.7% (36,525) of the total 85,537 units are seasonal and not used for year round housing. If forecasted future population (year round residents) are assigned to the residual 1990 housing, without adjusting that housing for vacation homes, then the growth in county population is incorrectly absorbed by the apparent "oversupply" of existing units. (The model actually produced a negative need for new housing).

To correct this problem, the total county forecasted supply of seasonal housing is subtracted from the county's total base year supply of housing, in that portion of the model that converts population forecasts into the estimate of future housing need. This more accurate accounting of housing resulted in the development of a new housing need equation. The following two equations show this process. The first equation converts forecasted population into housing need and the second equation estimates the total number of new houses that would have to be constructed to accommodate the future population.

$$\left(pop_{t+i} - graphs_{t+i}\right) \times ars.cohort \times ars.headship.rates = hhlds_{t+i}$$

where:

pop = total future population
grphs = total future estimated group housing
ars.cohort.rates = estimated % future population in each Age, Race and Sex cohort
ars.headship.rates = estimated % future population to head a household in each age, race and sex cohort
hhlds = total future household heads (total future households)
total.hsunits.needed = total housing units needed in the future (assuming each household needs a housing unit)

$$\left(hhlds_{t+i} - \left(dus_{t} - demo_{t+i} + conversions_{t+i} su_{t+i}\right)\right) \times vacant.rate_{t+i}$$

where:

hhlds = total future household heads (total housing units needed)
dus = total base year housing units
demo = total anticipalted demolitions between the base year and the forecast year
conversions = total anticipalted conversions from non-residential to residential units between the base year and the forecast year
su = total forecast year seasonal houses
vacant.rate = the percent of total housing expected to be vacant in the forecast year

After the county's new houses are assigned to municipalities and the total number of future municipal houses calculated (new houses plus the residual base year housing), the actual number of seasonal houses forecasted for the municipality is subtracted from the municipal total prior to calculating the municipality's future population. The following equation converts the assigned new dwelling units and the residual base dwelling units[21] into an estimate of total forecast year municipal houses. The adjustment for seasonal houses can be seen in this equation.

$$\frac{\Delta dus_{t+i} + \left(\left(\left(\frac{dus_t}{\sum rdus_t} \right) \times \sum_i^t rstockchange \right) + dus_t - su_{t+i} \right)}{1 + vacant.rate_{t+i}}$$

where:

Δdus = the change (+ or -) in municipal housing units at the forecast year
dus = total base year municipal housing units
rdus = total regional (county or counties) dwelling units
rstockchange = regional demolition +regional conversions
su = total forecast year municipal seasonal housing units

As suggested in the preceding text, alternative forecasts of seasonal housing have been prepared and are user selected in the PED model. The first alternative assumes that the 1990 supply of seasonal housing is constant into the future (the number of seasonal housing units in the future in each municipality is the same as the number reported in 1990). Other alternatives assume a 10%, a 15%, a 20% and a 25% increase in municipal seasonal housing in each of the four seashore counties of Cape May, Atlantic, Ocean and Monmouth. In all other counties the number of seasonal houses is held constant to 1990. The program also allows the user to enter their own estimate of future seasonal housing. With this alternative the user is presented with a worksheet into which the user can enter their own forecast of the number of seasonal houses in each of the 21 counties.

2. Residential Density Alternative

Between the subroutine that converts population into houses and the subroutines that convert future housing back into population forecasts, the PED model “fits” housing to available land in municipalities. The first version of the program used OSP estimates of the actual residential density for each municipality. These density numbers could be used as constants, or the user could select to increase or decrease these densities statewide (e.g. all municipal densities would be increased or decreased by the same percentage).

While the use of these 1986 constants at least resulted in new growth being assigned in keeping with the existing character of each municipality, there are two fundamental problems with using these historic densities to assigning future growth. First, densities tend to change over time. For example, the pattern of development in rural areas first is farms and a few towns. As development increases scattered single family large lot linear development along roadways. As more people wish to move into the municipality, small and then large developments are built generally providing a diversity of housing densities. The effect of this growth is to increase the overall residential density of the municipality. Second, the 1986 OSP estimates were calculated by dividing municipal dwelling units into the total estimated supply of non-job related developed land in the municipality. Therefore, the 1986 densities include allowances for new schools, new parks

[21] It should be noted that the regional stockchange is assigned proportionate to the number of base year dwelling units in each municipality. This method would be improved if OSP were to individually estimate the demolitions and conversions municipality by municipality.

etc. In many New Jersey counties, the demographic changes being forecast call for smaller household sizes and a decrease in the percentage of school age population. This type of forecast envisions increased residential development without substantial population increases. The added schools and parks included in the OSP 86 densities may not be needed or built.

a) Developing the Residential Density Alternatives

To gain a clearer understanding of residential densities, OSP undertook a careful examination of existing residential development patterns throughout the State[22]. Using aerial photoquads of the March 1986 flight (the most recent set available to OSP), approximately three samples of residential development were selected from each photoquad; in all 368 measurement were taken. Samples were selected based on clarity and recognition as single family housing development patterns[23]. The intent was to count housing units, not industrial, commercial or office uses.

To take the samples, twenty acre grids were placed on the photoquads. The number of housing units in each subsquare was counted and recorded, along with the photoquad number, sample number, Tier designation[24] (tiers used were the 1988 tier designations found in the Preliminary State Development and Redevelopment Plan, November 1988), and other characteristics, not germane for this discussion. For purposes of descriptive analysis, photoquads 1 through 53 were designated “northern” New Jersey, photoquads 54 through 92 “central New Jersey, and photoquads 93 through 177 “southern” New Jersey. The following table displays the frequency distribution of the samples and the discovered densities.

Table 2
DISTRIBUTION AND DENSITY OF 368 OBSERVATIONS OF NEW JERSEY
SINGLE FAMILY RESIDENTIAL DEVELOPMENT PATTERNS

PSDRP Tier	Sample Size	% total Samples	Average Density	Minimum Density	Maximum Density	Std. Dev.
1	20	05.4	4.02	1.70	6.30	1.43
2	96	26.1	2.45	0.65	5.25	1.08
3	42	11.4	2.05	0.15	4.00	0.86
4	62	16.8	1.42	0.15	3.50	0.79
5	45	12.2	0.77	0.05	4.05	0.80
6a	36	09.8	0.46	0.05	1.65	0.33
6b	27	07.3	0.30	0.05	1.15	0.29
7	40	10.9	0.84	0.05	2.65	0.61

[22] Gottlieb, Paul. Density Design and Infrastructure Costs. Trenton: New Jersey Office of State Planning, 1990
[23] this care was necessary since site visit verification was not performed.
[24] Tier 1: redeveloping cities and suburbs; tier 2: stable cities and suburbs; tier 3: suburban and rural towns; tier 4: suburbanizing areas; tier 5: exurban reserve; tier 6a: agricultural areas; tier 6b: environmentally sensitive agricultural areas; tier 7: environmentally sensitive areas.

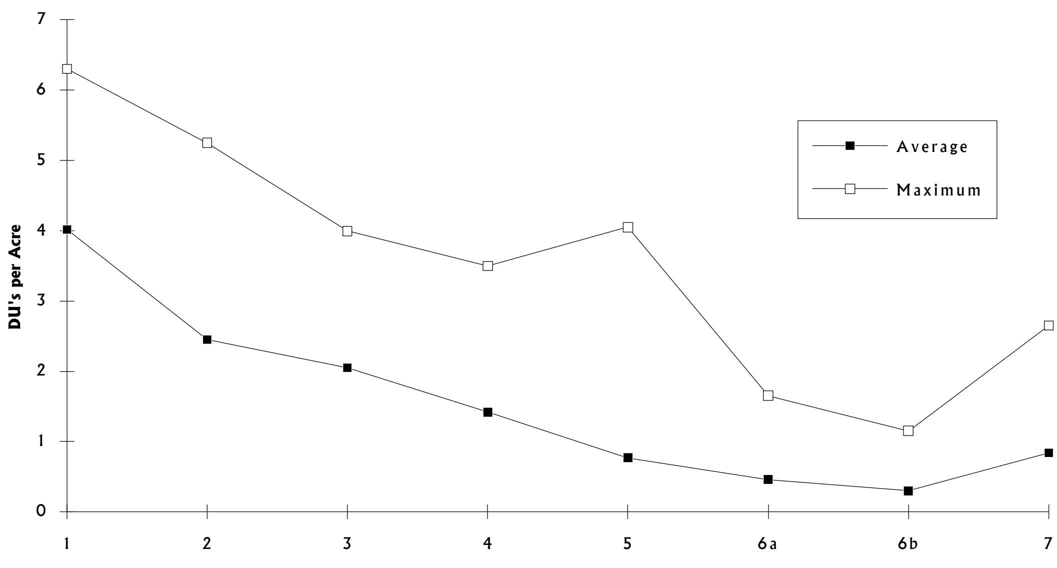
Region	Sample Size	% total Samples	Average Density	Minimum Density	Maximum Density	Std. Dev.
Northern	161	43.8	1.56	0.05	6.30	1.37
Central	98	26.6	1.65	0.05	5.25	1.28
Southern	109	29.6	1.55	0.05	5.40	1.19

Several conclusions can be drawn from the preceding table. First, after controlling for tier (using an ANOVA procedure), there does not appear to be any significant difference in single family density in the northern, central or southern regions of the State. This finding runs counter to widely-held beliefs about residential development in different parts of the State[25]. This finding also supports the use of a single set of density adjustments statewide.

Second, the data shows that average residential development densities, even single family densities, appear to vary predictably by Tier. Average densities in our sample declined smoothly from Tier 1 to Tier 6b before rising again in tier 7, as shown in the following chart. Maximum densities also followed this pattern except in tier 5, where much higher densities are recorded. Statistical tests suggest that the differences in average density do, in fact, represent real differences in the residential densities underlying the sample. There are two exceptions: densities in tiers 6a and 6b, as well as 5 and 7, cannot reliably be said to differ from each other.

Chart 1

AVERAGE AND MAXIMUM DENSITIES BY TIER



This information about residential density was used to prepare several alternative residential densities for use in the PED model. Average density was used in some alternatives, in lieu of the estimated density prepared by OSP. Maximum density was used to simulate residential densities that resulted from a mix of single and multi family housing types. Most alternatives allow

[25] See, for example, South Jersey Land Plan Coalition, "Land Availability Under the Preliminary State Development and Redevelopment Plan", May 1990, p.4.

the user to simulate the difficulty of developing higher density developments in neighborhoods with high incomes. This resistance to change reflects the higher hedonic values of such places that usually translate into higher housing costs. With these income sensitive switches, the user selects the 1990 average income level that would tend to dampen the use of higher densities (fitting would only occur at the densities estimated by OSP, based on 1986 aerials). The following is a list of the density alternatives available to the model user.

a. Fits86 - OSP estimated municipal specific densities.

B. Incave - The use of the municipality's tier average, unless the 1990 mean household income exceeds a user selected amount in which case Fits86 is used.

C. Incmax - The use of the municipality's tier maximum density, unless the 1990 mean household income exceeds a user selected amount in which case Fits86 is used.

D. Inchave - The use of the highest density, of either the fits85 or the incave density, unless the mean 1990 household income exceeds a user selected amount in which case Fits86 is used .

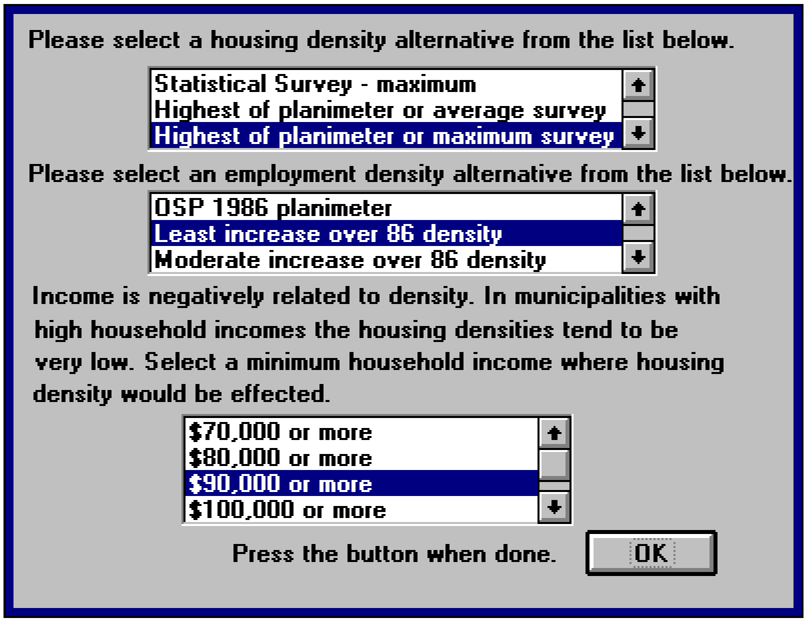
E. Inchmax - The use of the highest density, of either the fits85 or the incmax density, unless the mean 1990 household income exceeds a user selected amount in which case Fits86 is used .

b) Incorporating the Residential Alternatives into the PED

At the beginning of the PED, the model user is prompted to select all of the variables that the PED requires; including the residential density variables. Once the user selections are made, they are stored until the PED is 'fitting' mathematically assigned growth to the municipal supplies of available, developable land. During this Trend fitting process the user selected density option is used.

The following displays the screen viewed by the model user to select the residential density variables. Following the screen graphic is a list which relates the screen options to the density and income alternatives.

Screen 1
HOUSING DENSITY ALTERNATIVES INPUT



Screen Alternative	Density Alternative
OSP 1986 planimeter	FITS86
Statistical Survey - average	INCAVE
Statistical Survey - maximum	INCMAX
Highest of Planimeter or average Survey	INCHAVE
Highest of Planimeter or maximum Survey	INCHMAX

3. Improved housing to population estimation

At the beginning of the PED model, population is converted into an estimate of total future year housing need. The model then “fits” the new housing to municipalities. Finally, the model needs to re-convert total municipal houses back into a municipal population forecast. As originally designed, earlier versions of the model use a simple persons to housing unit ratio to make the population forecast. This means that once county population had been converted into an estimate of total county houses at the beginning of the program, this ratio was then used at the end of the program to convert municipal housing back into municipal population. The problem with this method is that it produces only county average estimates of population and not municipal specific estimates.

Under the current work program, OSP agreed to develop a method to estimate the number of households by household size in each municipality. It then became evident that if the number of municipal specific households by size could be forecast, then these household size forecasts could be used to forecast municipal population.

a) Model Research

To begin the project, OSP initiated a research project to discover an alternative method to forecast household sizes. This search failed to locate any articles describing methods to forecast municipal household sizes (or any household sizes for that matter). However, nine articles were located which report various topics related to household formation and to household income and labor force participation, both of which are factors related to household formation. Turnbull (1990) reports a model for household location which relates location to housing cost. Mutchler and Burr (1991) report that living arrangements for older persons are related to income and the health of the householder. Burch and Matthews (1987) describe several theories relating real income, availability of kin, changing preferences for privacy, role changes for women, housing conditions and declines in household services to household location and formation. Wojtkiewicz, McLanahan and Garfinkel (1990) relate the growth of female households to population growth, fertility changes, decreased marriages and increased divorces. Spain (1990) reports that residential mobility is linked to quality of life factors. Because there might be a strong relation between household location and household by size, the work of Pollakowski and Wachter (1989) was reviewed. This research reported the relationship between household income, utility costs, interest rates and proximity to jobs to the supply of housing.

These factors then were reviewed to see if they were projected by other subroutines in the OSP model. For example, utility costs are not projected by the model, so this factor was excluded from further consideration. On the other hand, the OSP model projects population and density (a possible index for preference for privacy or quality of life), therefore these variables were continued for further study. The following table identifies the variables selected for study and identifies the source for each of the variables.

Table 3
SOURCES FOR VARIABLES USED TO PROJECT HOUSEHOLDS BY SIZE

	Turnbull	Mutchler	Burch	Wojtkiewicz	Spain	Pollakowski
hhi	**x**	**x**	**x**		**x**	**x**
pop90			**x**		**x**	
emp90					**x**	**x**
deltae89					**x**	**x**
delta89			**x**	**x**		**x**
pden1990			**x**		**x**	**x**
hholds90			**x**			
hhpop90			**x**			
pphh90		**x**		**x**		
rate89			**x**	**x**		

hhi **-** mean municipal household income in 1990
pop90 **-** total 1990 municipal population
emp90 **-** total private sector jobs in each municipality (ES 202)
deltae89 **-** the change in private jobs between 1980 and 1990 in each municipality
delta89 **-** the change in population between 1980 and 1990 in each municipality
pden1990 **-** municipal population 1990 divided by municipal area in square miles
hholds90 **-** the number of households in each municipality in 1990
hhpop90 **-** the municipal household population in 1990
pphh90 **-** the average persons per household in each municipality in 1990
rate89 **-** the rate of municipal population change between 1980 and 1990

The variables then were compared to the number of households, in each municipality, with one, two, three, four, five or six or more persons in the household. Based on the results of this correlation test, the variables 'pphh90' and 'hhpop90' were dropped because no relationships were demonstrated. Data sets for each variable then were examined to insure the data had as normal a distribution as possible. Where needed the data was transformed to normalize the data. Stepwise regressions then were performed with municipal households, by household size category (e.g. the total number of one person households in each municipality, etc.), being selected as the dependent variable and all other factors identified as independent variables. The results of the regressions were then tested for problems related to colinearilty, variance and normality of residuals. Table 2 summarizes the findings and displays both the R^2 for the equation and the coefficient for each variable in the statistical equation.

Table 4
REGRESSION ANALYSIS - VARIABLES AND RESULTING COEFFICIENTS

	per1	per2	per3	per4	per5	per6plus
log(hholds90)	*.933064*	*.958916*	*.978848*	*.979635*	*.956070*	*1.034898*
pop90						
log(emp90)	*.102866*		*.021701*			
log(hhi)	*-.645910*	*.060435*	*.231700*	*.487358*	*.309556*	*-.243137*
log(deltae89)						
log(delta89)						
pden1990						
rate89						
constant	*5.023854*	*-1.48002*	*-4.16827*	*-6.83401*	*-5.55141*	*-1.02579*
R^2	.95820	.99443	.98404	.95388	.91203	.86207

per1 = total number of 1 person households in each municipality
per2 = total number of 2 person households in each municipality
per3 = total number of 3 person households in each municipality
per4 = total number of 4 person households in each municipality
per5 = total number of 5 person households in each municipality
per6plus = total number of 6 or more person households in each municipality

The resulting equations exhibit a very good fit of the real world data. To test the nature of the model's accuracy, the predicted number of households by size was compared to the actual household information from Camden County. The choice of Camden County was arbitrary. However, the county contains low income urban areas, high income suburban areas, municipalities that are losing population and rapidly growing places, and therefore contains a number of traits that would prove useful in testing the model. Table 3 compares the model's ability to estimate total households by household size with the actual Census data. The diagrams following this table display the model's ability to estimate municipal households for each of the six household sizes.

Table 5
COMPARISON OF TOTAL ACTUAL AND MODELED HOUSEHOLDS BY HOUSEHOLD SIZE
CAMDEN COUNTY - 1990

Number of Households	1990 Census	OSP Model	MAPE
1 person Households	41,541	45,642	.0987
2 person Households	51,550	56,173	.0896
3 person Households	32,412	32,952	.0167
4 person Households	29,857	28,668	-.0398
5 person Households	14,545	13,397	-.0789
6 or more person Households	8,853	7,992	-.0973

Chart 2a

COMPARISON OF ACTUAL AND MODELED NUMBER OF 1 PERSON HOUSEHOLDS
CAMDEN COUNTY - 1990

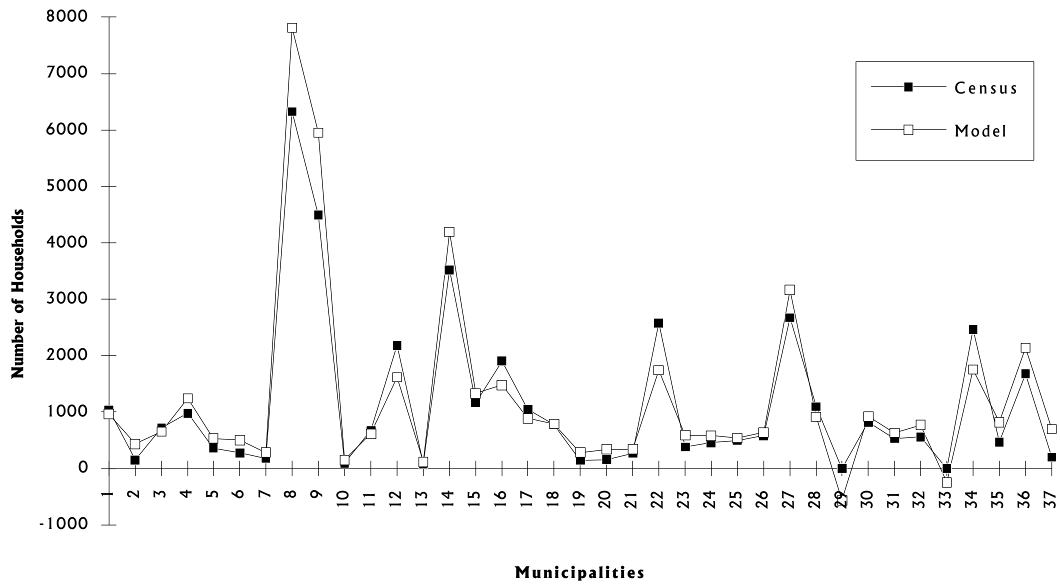


Chart 2b

COMPARISON OF ACTUAL AND MODELED NUMBER OF 2 PERSON HOUSEHOLDS
CAMDEN COUNTY - 1990

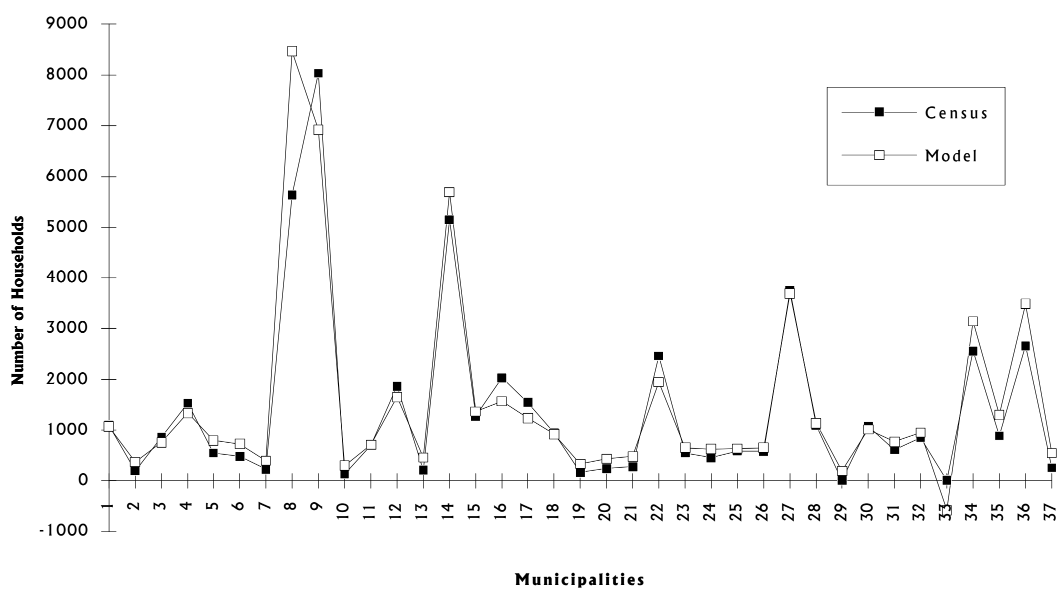


Chart 2c

COMPARISON OF ACTUAL AND MODELED NUMBER OF 3 PERSON HOUSEHOLDS
CAMDEN COUNTY - 1990

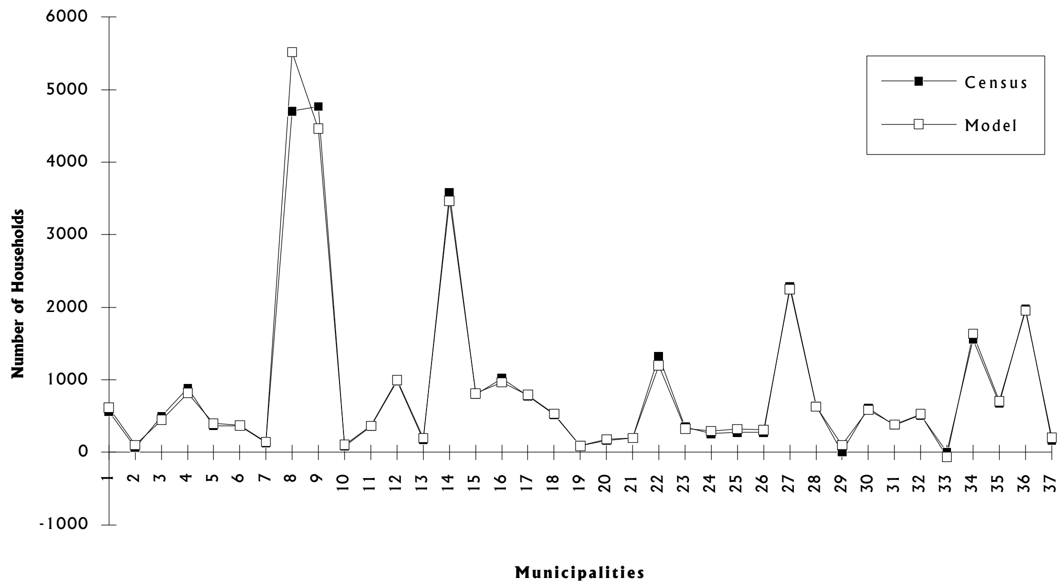


Chart 2d

COMPARISON OF ACTUAL AND MODELED NUMBER OF 4 PERSON HOUSEHOLDS
CAMDEN COUNTY - 1990

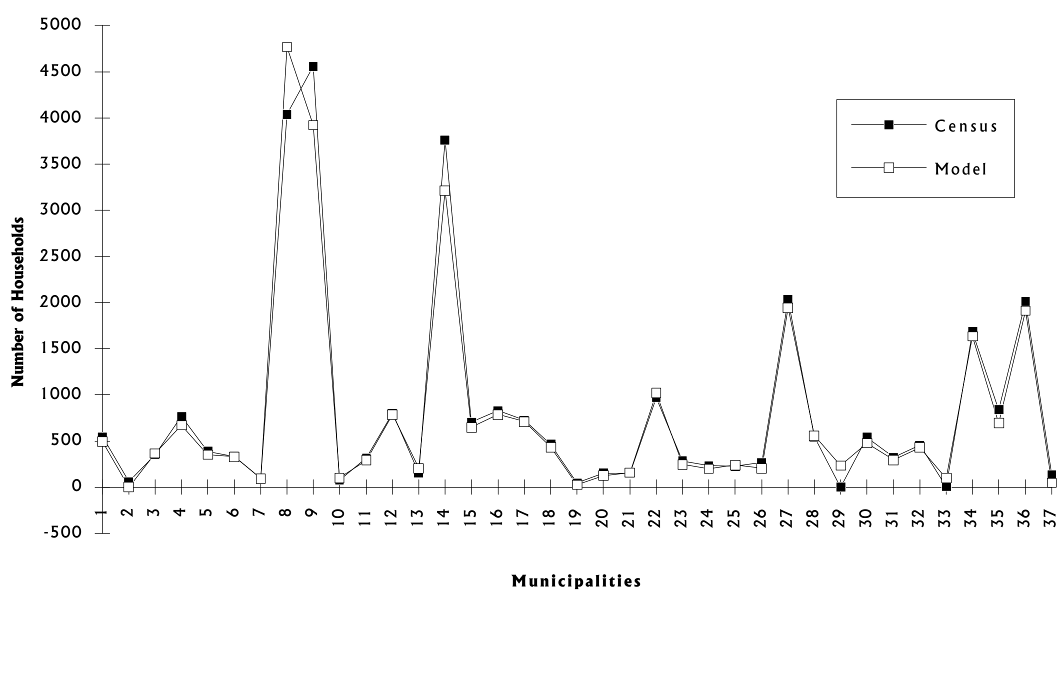


Chart 2e

COMPARISON OF ACTUAL AND MODELED NUMBER OF 5 PERSON HOUSEHOLDS
CAMDEN COUNTY - 1990

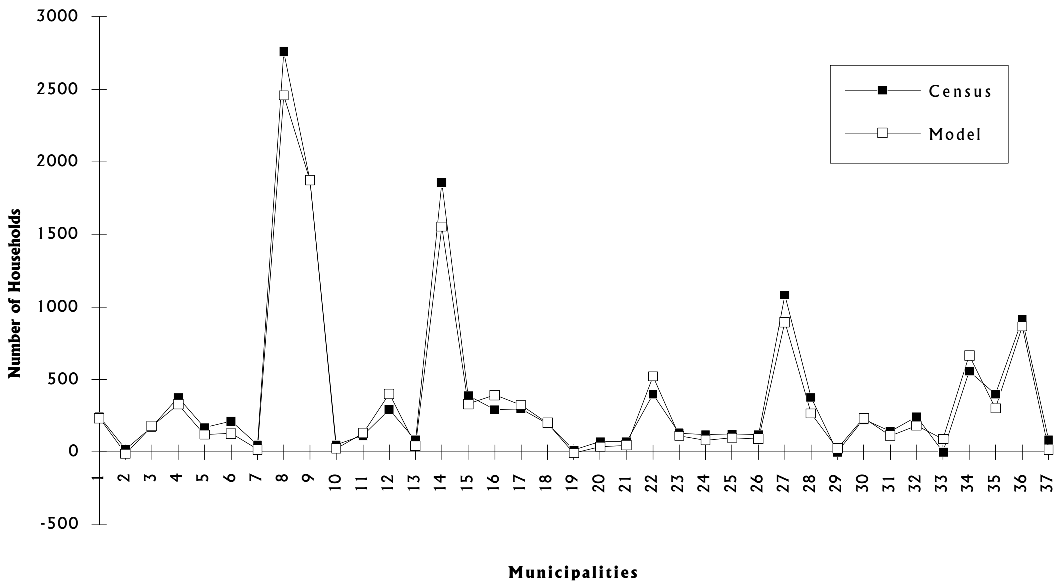
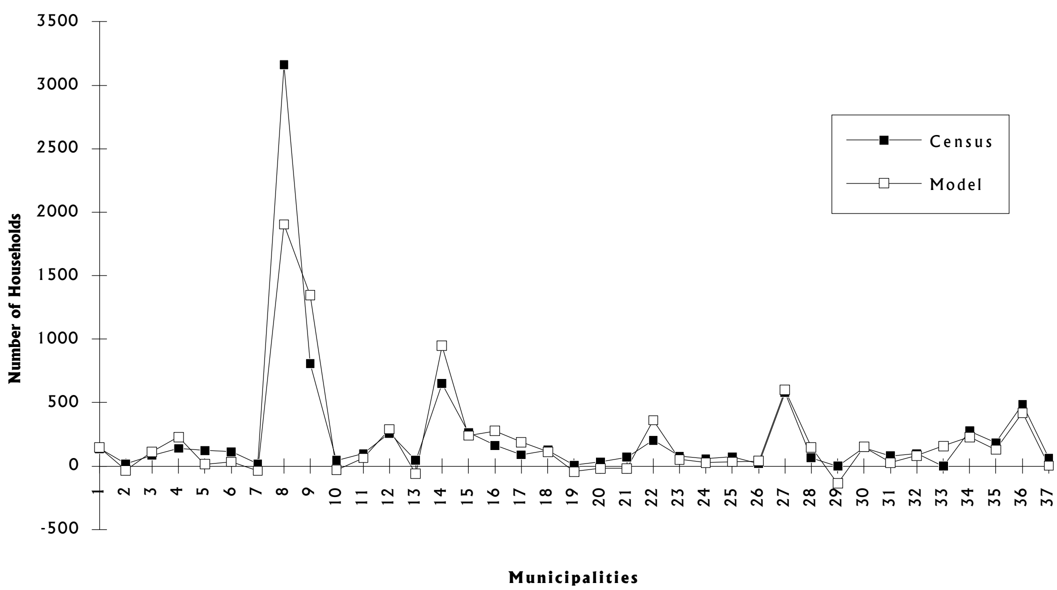


Chart 2f

COMPARISON OF ACTUAL AND MODELED NUMBER OF 6 OR MORE PERSON HOUSEHOLDS
CAMDEN COUNTY - 1990



From the preceding analysis, the following observations were made:

• The model appears to overproject households with 3 or less persons and to underproject larger households. Curiously, the model is most accurate in projecting 3 and 4 person households and its error grows as household size increases or decreases from this middle-size range. The nature of the MAPE suggests that there might be another explanatory variable yet to be discovered.

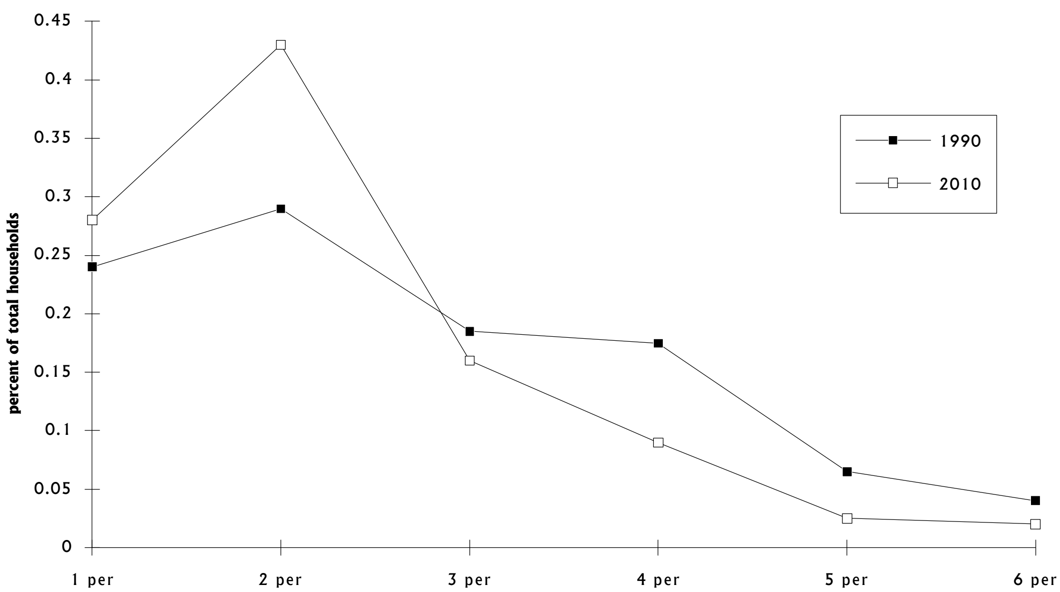
• The largest errors occur in the larger municipalities and the direction of the error is consistent with the preceding observation.

b) Testing the Model

The resulting equations were incorporated into the PED model and the results of the model distributed for comment in December 1993 to Urbanomics, NJ DOT and NJ Transit officials. The result of this project team internal analysis was that the model, while effective at back-casting 1980 to forecast 1990, underestimated the number of future households by size group in the 2010 test year. After some analysis it was realized that the model's equations implicitly assumed 1990 household formation patterns. The Urbanomics forecast for 2010 assumed that average household size would decline from the 1990 statewide average of 2.51 persons per household to approximately 2.3 persons per household in the year 2010 (and then remain constant thereafter). Therefore the coefficients needed to be adjusted to reflect the forecasted change in household size. The following chart displays the percentage of households by size that resulted from the original equation and the result of adjustments made to the total household coefficient.

Chart 3

1990 AND 2010 HOUSEHOLD SIZE CENTER POINTS



Again the PED program was revised to include the 2010 coefficients and model results produced. This time the model results were distributed for comment to project team members, the twenty one County Planning offices, and to the Delaware Valley Regional Planning Commission (DVRPC). Specific comments were provided by nine county planning offices and DVRPC. In general the comments could be summarized into four types:

1. The Barrier Islands absorbed too much growth and the mainland communities were allocated too little growth. This problem occurred in Ocean and especially in Cape May County.
2. Most municipalities look all right, but some seemed to grow too much and some seemed to grow too little.
3. Some large older Municipalities that had been stable or growing, suddenly were forecast to decline, thereby causing a larger than expected amount of growth to shift into the developing part of the counties.
4. The housing need projected by the model appears to be too large.

(1) The Barrier Island Overassignment Problem

The Barrier Island problem has been resolved with the cooperation of the Ocean County and Cape May County Planning Offices. Three causes for the overassignment problem have been identified. First, the supply of available land on the Barrier Islands was substantially overstated by the satellite analysis performed by Rutgers University. This problem was noted when county planners reviewed OSP's land inventory data. This problem was resolved by OSP planimetering its own aerial analysis of available land.

The second cause of the problem was the model's method of assigning seasonal housing on a county proportionate method. This error was corrected by assigning seasonal housing on a municipality by municipality basis (as described earlier in this report).

Finally, it has been discovered that the Census substantially understated the number of seasonal houses, and instead mistakenly identified these units as vacant. The model then assigned population to these vacant units, resulting in a good part of the barrier island overassignment problem. Corrected vacant housing estimates are being complied by the County planning offices for use with the model. Test runs using lower levels of non-seasonal vacancy resulted in more satisfying projections.

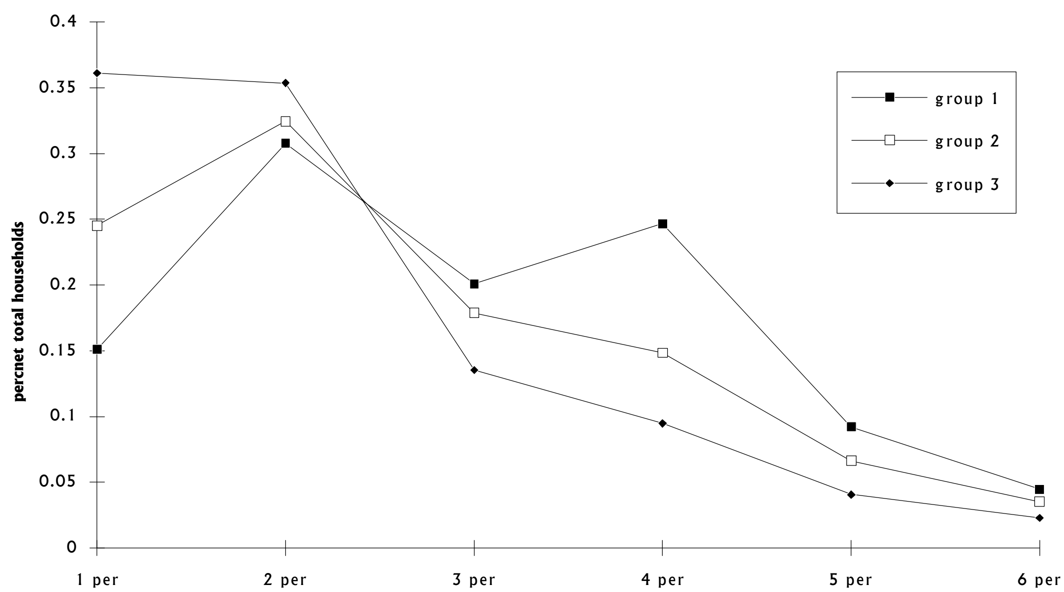
(2) The Too Little or Too Much Assignment Problem

The too little/too much assignment problem prompted OSP to undertake a more detailed statistical analysis of the percentage of households by household size in each municipality. This investigation hypothesized that the use of a single set of equations to convert houses into population would result in some places appearing to be high or low, if there was a real statistical difference between the municipalities. Cluster analysis discovered three groups of municipalities.

The following chart displays the average percentage of each household size for each of the three groups.

Chart 4

CENTER POINTS FOR EACH MUNICIPAL GROUP - 1990



Based on the cluster (group) identity of each municipality, separate regressions were performed to relate the number of households by size to the factors already discussed in this paper and to two new hybred variables: the rate of change in dwelling units and the rate of change in employment. The following tables display the results of this analysis.

Table 6
GROUP1 - 267 MUNICIPALITIES

	log(per1)	log(per2)	log(per3)	log(per4)	log(per5)	log(per6plus)
log(hholds90)	*1.017845*	*.955480*	*1.005502*	*.993792*	*.978652*	*1.044395*
pop90						
log(emp90)		*.020108*				
log(hhi)	*-.473594*	*.116371*	*.083351*	*.185044*		*-.417378*
log(deltae89)						
log(delta89)						
log(pden1990)	*.041465*	*-.015311*				
rate89						
log(dur89)				*.027208*	*.024027*	
log(empr89)						
constant	*2.824895*	*-2.15162*	-2.55259	*-3.49223*	*-2.188*	*.913057*
Adjusted R^2	.96137	.99160	.99517	.98745	.96431	.88496

Table 6 (continued)
GROUP 2 - 228 MUNICIPALITIES

	log(per1)	log(per2)	log(per3)	log(per4)	log(per5)	log(per6plus)
log(hholds90)	*1.010075*	*.975311*	*1.019756*	*1.009129*	*1.014579*	*1.094073*
pop90						
log(emp90)						
log(hhi)	*-.217193*	*.143312*	*.098165*			*-.426798*
log(deltae89)						
log(delta89)						
log(pden1990)	*.045996*	*-.032314*				
rate89						
log(dur89)						
log(empr89)						
constant	*.470263*	*-2.18978*	*-2.94439*	*-1.97659*	*-2.87963*	*.218954*
Adjusted R^2	.98874	.99431	.99313	.98355	.96503	.90678

GROUP 3 - 72 MUNICIPALITIES

	log(per1)	log(per2)	log(per3)	log(per4)	log(per5)	log(per6plus)
log(hholds90)	*.963801*	*1.030764*	*.980475*	*1.042598*	*1.119625*	*1.083558*
pop90						
log(emp90)	*.036565*	*-.053870*				
log(hhi)			*.243822*			
log(deltae89)						
log(delta89)						
log(pden1990)		*-.070790*	*.143270*	*.141579*		
rate89						
log(dur89)						*-.103426*
log(empr89)						
constant	*-1.06835*	*-.278308*	*-5.58395*	*-3.89491*	*-4.23020*	*-4.75473*
Adjusted R^2	.99376	.99352	.98409	.96702	.92639	.89834

Discriminant analysis[26] (a statistical procedure) of the three groups revealed that household income, municipal density and the rate of employment change were significantly correlated (.6104) with differentiation between the three groups. From the preceding table it also can be seen that income and density are important variables in many of the household size equations.

Municipal identities were then coded to identify group membership, and the three model equations then were used to forecast (backcast) 1990 population in Camden county, given Census data about the number of housing units, density and mean household income. While the results of this exercise were generally fairly good at estimating total households in each municipality, the model equations appeared to be over estimating one person households and underestimating other household size groups. This resulted in the model producing inaccurate estimates of the number of persons in each municipality; the purpose of the exercise.

To investigate this problem several statistical examinations were conducted. It was discovered that some of the model variables, while significant, were ill-conditioned. The number of variables was reduced in most equation to resolve this problem. (This also resulted in different coefficients being used). The corrected equations then were again used to backcast the 1990 municipal population of Camden County. The results of this test were substantially more satisfying and are displayed in the following table and diagrams. Differences in census and modeled results can be seen in the following diagrams to be primarily centered in one municipality (Camden City).

[26] Wilksl Lambda

Table 7

COMPARISON OF TOTAL ACTUAL AND REVISED MODEL HOUSEHOLDS BY HOUSEHOLD SIZE
CAMDEN COUNTY - 1990

Number of Households	1990 Census	OSP Model	MAPE
1 person Households	41,541	40,546	-0.239
2 person Households	51,550	55,429	0.075
3 person Households	32,412	32,957	0.016
4 person Households	29,857	29,523	-0.011
5 person Households	14,545	13,560	-0.067
6 or more person Households	8,853	5,944	-0.328

Chart 5a
Comparison of Actual and Revised Model - Number of 1 Person Households
Camden County - 1990

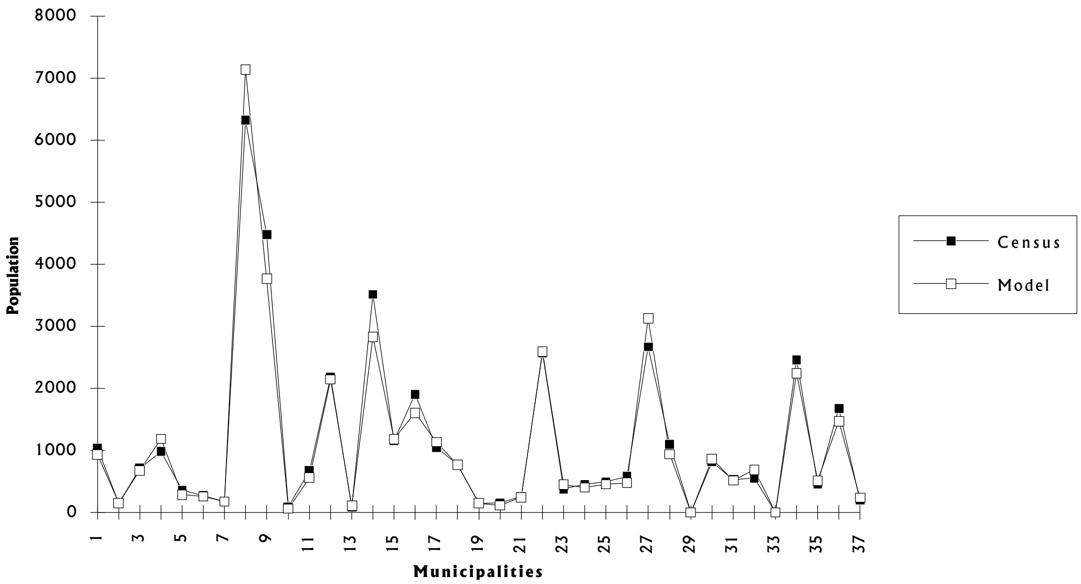


Chart 5b

COMPARISON OF ACTUAL AND REVISED MODEL - NUMBER OF 2 PERSON HOUSEHOLDS
CAMDEN COUNTY - 1990

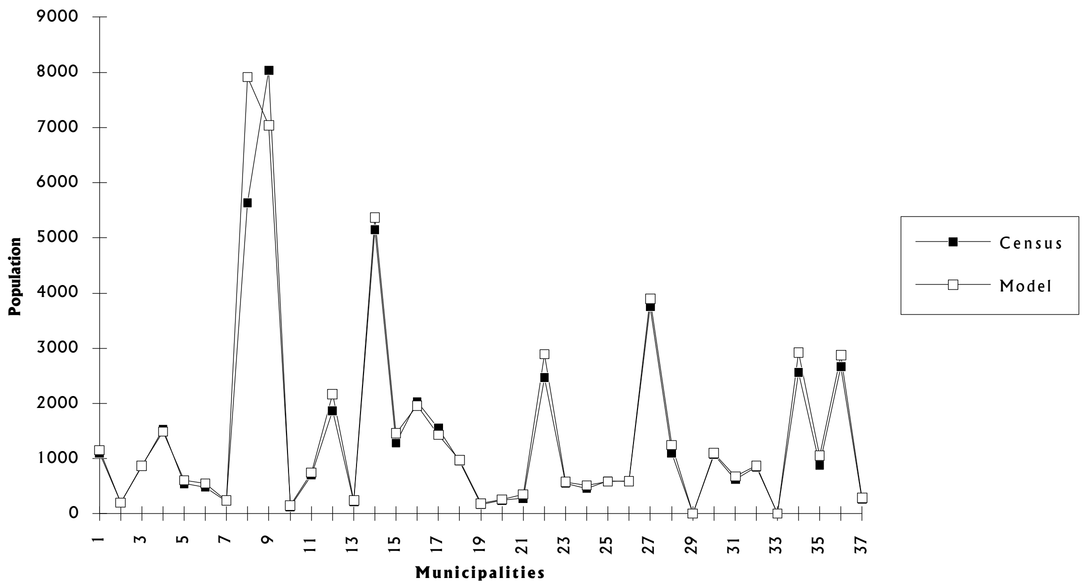


Chart 5c

COMPARISON OF ACTUAL AND REVISED MODEL - NUMBER OF 3 PERSON HOUSEHOLDS
CAMDEN COUNTY - 1990

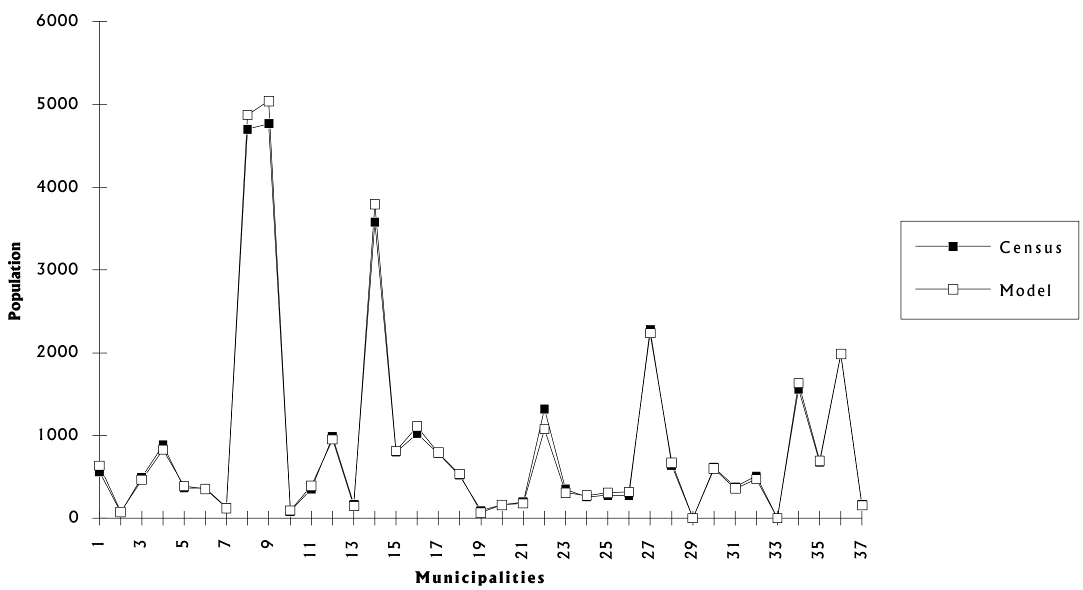


Chart 5d

COMPARISON OF ACTUAL AND REVISED MODEL - NUMBER OF 4 PERSON HOUSEHOLDS
CAMDEN COUNTY - 1990

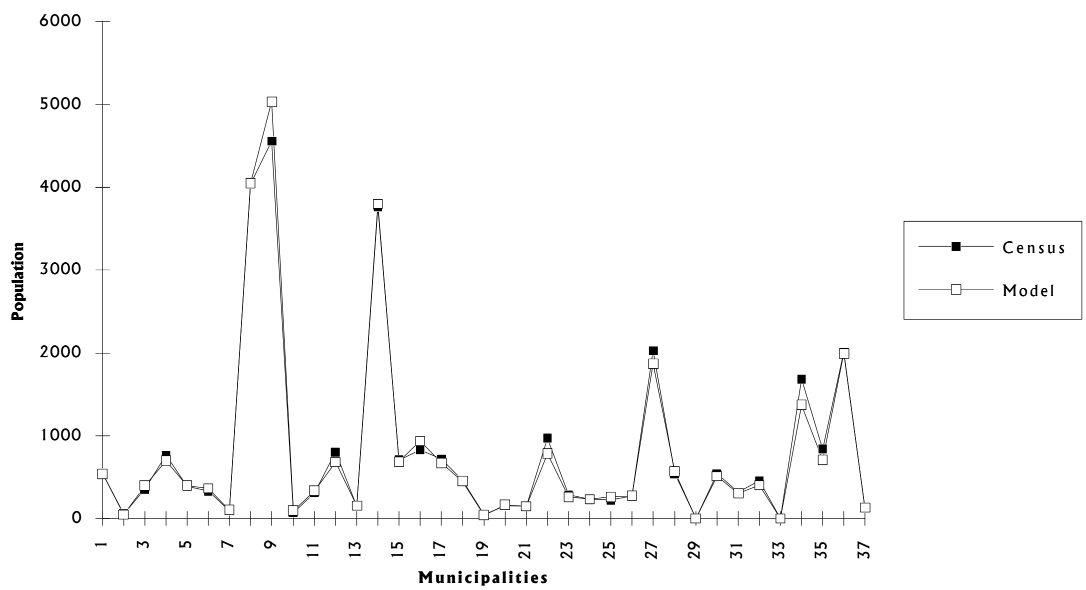


Chart 5e

COMPARISON OF ACTUAL AND REVISED MODEL - NUMBER OF 5 PERSON HOUSEHOLDS
CAMDEN COUNTY - 1990

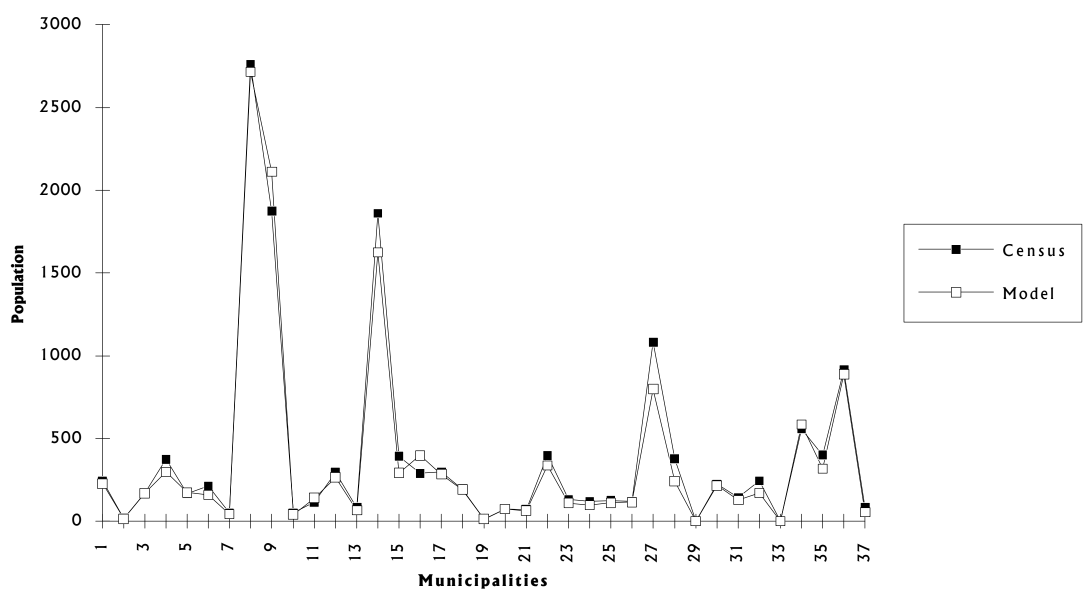
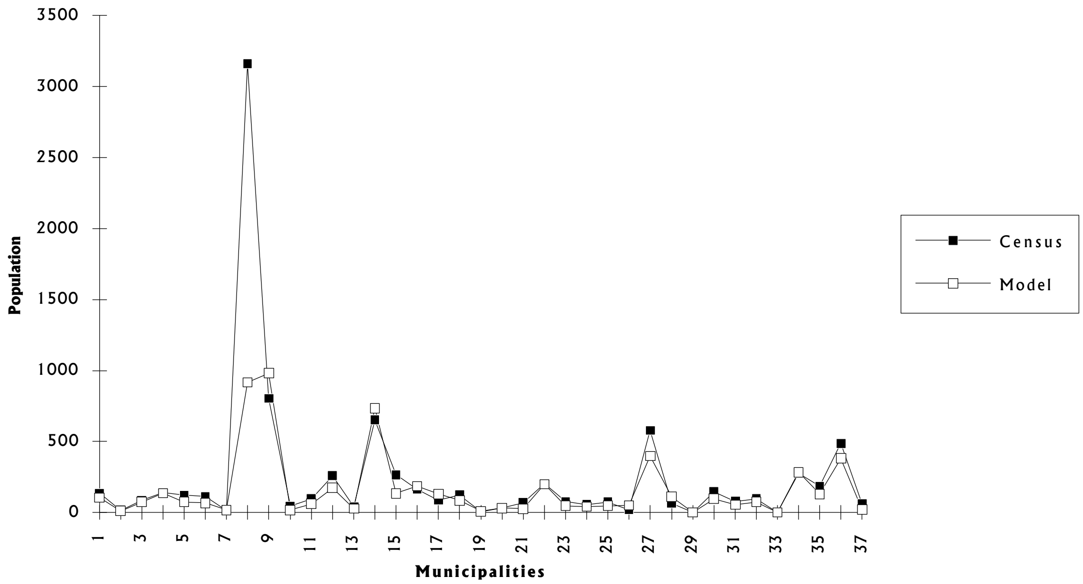


Chart 5f

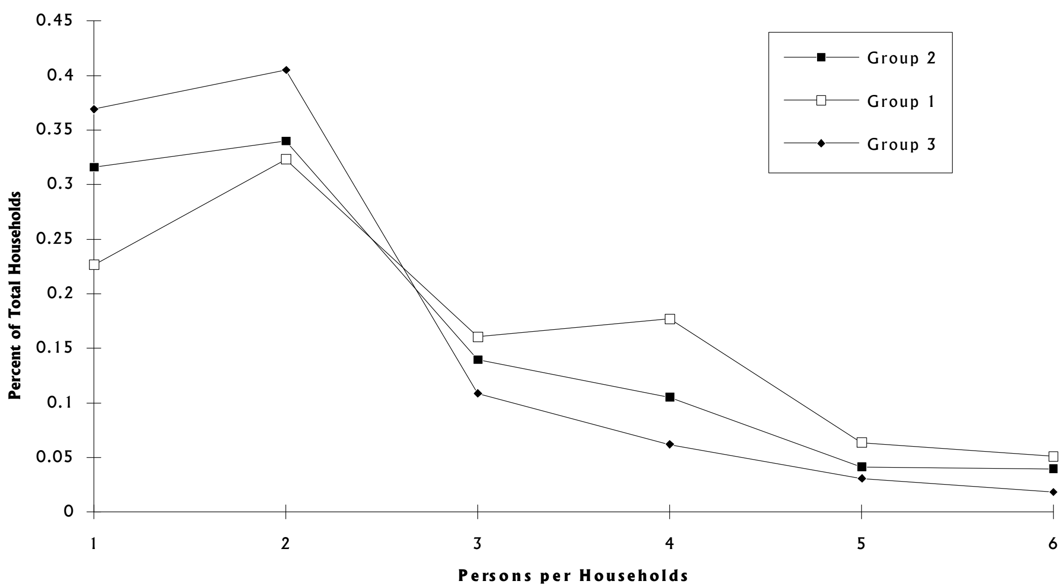
COMPARISON OF ACTUAL AND REVISED MODEL - NUMBER OF 6 OR MORE PERSON HOUSEHOLDS
CAMDEN COUNTY - 1990



To forecast future population, the equations for each household size for each municipal group had to be modified to reflect future expected household preferences. There is no scientific way to effect this change. The resulting revisions were accomplished essentially by trial and error, and reflect the concept that each group changes but continues to look much the way it did in 1990. The following diagram displays the resulting equations.

Chart 6

ESTIMATED CENTER POINTS FOR EACH MUNICIPAL GROUP - 2010

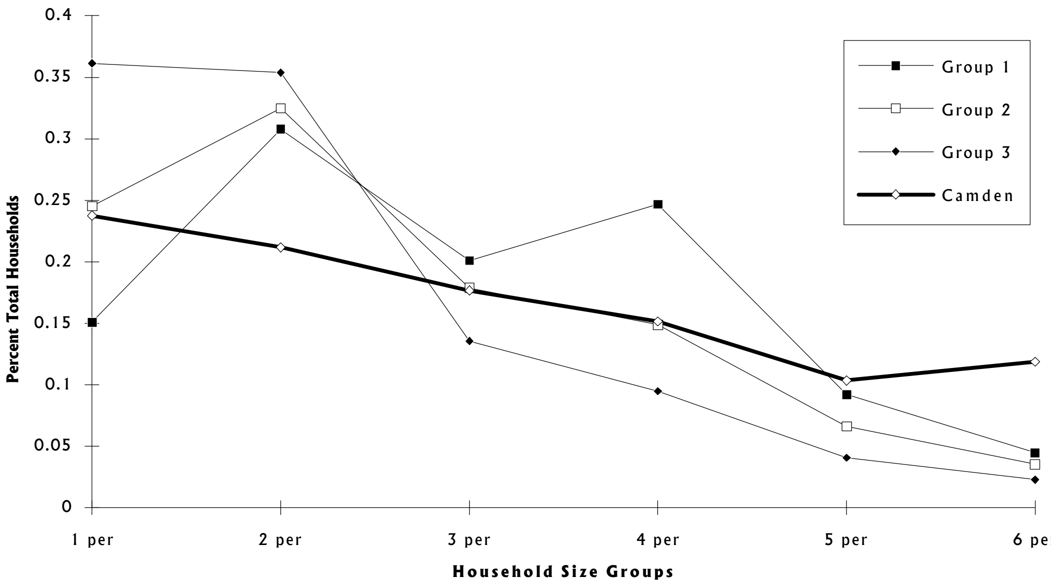


(3) Larger Stable Municipalities Suddenly Forecast to Decline

In the preceding section it can be seen that municipality #8's (Camden City) revised projections of households did not conform to the Census. In particular, the model seriously over-estimated two person households and seriously underestimated the number of six person households. This type of error would result in an over-all under-estimation of future population. What make Camden City and some other municipalities unusual is displayed in the following diagram.

Chart 7

GROUP CENTER POINTS COMPARED TO CAMDEN CITY - 1990



Despite its unusual household size characteristics, Camden City was not statistically differentiated as a separate municipal group. Statistically, the City is part of the municipal group 2.

To improve the results of the model, coefficients for 1990 were developed which replicate the Census results for Camden. It is assumed that these coefficients will remain constant, due to the unusual nature of the city's household distribution, especially the lange number of 6 or more person households. In addition, several other cities were noted as having similar large household size characteristics. (OSP identified all municipalities which increased their person per household average between 1980 and 1990, and that had 1990 average household sizes of at least 3). In the PED, these other cities are forecasted using the same 1990 constant coefficients developed for Camden. The following is a list of the municipalities were the Camden coefficients are used.

East Newark	Camden City
New Brunswick	Plainfield City
Passaic	Patterson

(4) The Too Many Houses Problem

NJ DOT noted that the revised municipal projections prepared by OSP showed a sudden and unreasonable increase in the number of houses between 1990 and 1995. Because of this forecast, NJ DOT models would project more trips than was thought reasonable.

To correct this problem OSP obtained STF 2 1990 Census data to construct new headship tables for use with the PED. The resulting 1990 Census headship rate table was then used to forecast houses and average household sizes. It was discovered that the use of these new rates produced very little difference between the test forecasts done in March and the new projections. After some thought it became clear that the cohort table used in the model to project the number of persons in each age/race/sex group had to be in error. OSP then constructed new cohort tables utilizing the recently published county forecast series produced by the New Jersey Department of Labor. New model runs were produced which used the 1990 headship rates and the new cohort tables. The resulting number of houses was substantially reduced and the resulting average household sizes for the revised series was remarkably close to those forecasted by WEFA, as shown in the following table. It should be noted that the WEFA population numbers include group housing and that the real average household numbers would be slightly lower than those shown (very slightly lower).

Table 8
COMPARISON OF AVERAGE HOUSEHOLD SIZES - WEFA AND OSP

	WEFA	Revised OSP
1995	2.64	2.65
2000	2.60	2.61
2005	2.57	2.57
2010	2.53	2.53
2019	2.40	2.5

The WEFA forecast projects average household size in 2019 of 2.4 persons. However, the WEFA forecast does not forecast as many people in the state as does the Urbanomics forecast, and since the engine fueling the increased Urbanomic growth is Hispanic and Asian immigration; it might not be unreasonable for the average household size to be larger than that proposed by WEFA.

C. IMPROVED EMPLOYMENT FORECASTS

1. The Office Fitting Model

In brief, the original PED model subtracted total future employment from base year employment and then fitted the residual (new) employment to the available land in a municipality. At the time (1988) this program was written, New Jersey was undergoing a period of rapid employment growth and forecasts of continued strong employment growth were predominant. Therefore, the model assumed that continued rapid employment growth could only be accommodated by a corresponding increase in the supply of new buildings. Office space vacancy occurred primarily in the older developed areas where employment had stabilized or declined.

However, shortly after the model was completed the National and State economy entered a recession/depression. From 1989 through 1992, the State's total employment not only failed to grow but actually recorded a decline of approximately 200,000 jobs.[27] During the same period of time, the inventory of office space increased as building planned and under construction were completed. For example, in 1989 alone, 3.7 million square feet of new office space was constructed in the 11 county Northern region of State[28]. By 1993, it was felt that a large supply of office space existed in the State and that a substantial portion of the future growth in jobs would be attracted to residual 1990 space. Because of this attraction to the residual 1990 vacant space, the model's employment assigning algorthim needed to be modified.

Given that the real estate market for office space was to be simulated, it became important to identify the important variables in the market and then to relate them in a meaningful way. To identify the main variables, telephone interviews were conducted and a literature search of the real estate and economic literature was undertaken. In addition, the following companies provided senior personnel to be interviewed: Bender and Company; Prudential Reality; Metropolitan Life Reality; Greystone Reality; Sitar and Company; the Building Owners and Managers Association (BOMA's national, Chicago and New Jersey chapters); Cognetics Real Estate, Inc; and, the Institute of Real Estate Management. OSP also discovered that the communications and power utility companies have developed modeling capabilities to forecast new office demand. Therefore, the following organizations were contacted and provided information for this study: New Jersey Bell; PSE&G, Electrical Power Research Institute, and the State of California Energy Commission. The resulting equations display the relationships that were discovered.

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[27]For the years from the beginning of 1990 through 1992 the State lost a total of 190,222 jobs, based on US BLS data as reported by Urbanomics.

[28]F.W. Dodge Company unpublished report of construction starts of office buildings, banks and financial buildings, capitols, court and city buildings provided to OSP by Urbanomics.

FUTURE DEMAND FOR OFFICE SPACE = f(EMPLOYMENT) • EXISTING F PER EMPLOYEE •
CHANGES IN SPACE UTILIZATION IN THE WORKPLACE

RESIDUAL 1990 OFFICE SPACE = EXISTING INVENTORY • DECAY RATE

DEMAND FOR NEW OFFICE SPACE = FUTURE DEMAND - (RESIDUAL 1990 OFFICE SPACE • NATURAL VACANCY)

a) The Relationship Between Employment and Office Space

(1) The Existing inventory of Office Space

The task of collecting information about the existing (1990) inventory of Office space was conducted by Urbanomics. Three estimates of county Office space were compiled: Black's Guide; Bender & Company report; and, Cushman and Wakefield report. A single source (Black's Guide) was available at the municipal scale. Because Black's Guide provided a consistent set of data at both the county and the municipal scale, this data set was exclusively used in the following analysis. The inventories are included in Appendix B of this report.

Several technical problems were apparent with the office space inventory. First, data was not available for five of the twenty-one New Jersey Counties or for all the municipalities in these counties. In fact, municipal office space inventories were reported for only 220 of the 473 municipalities in the 16 county area covered by Black’s. With respect to the 253 reported municipalities reported with zero office space, it was not clear if Black’s was reporting “no data available” or if the actual inventory was zero square feet. OSP tried to improve the data set in two ways. First, OSP contacted both municipal and county planning and economic development personnel and ask them to review the inventories and provide corrections. Secondly, selected Realtors were contacted to learn if they maintained inventory records or even to learn of their intuitive estimates of the office space inventory. Neither of these procedures produced information that was useful to the study.

Another type of technical problem involved the definition of just what was being reported in the Black's Guide inventory. Urbanomics reported that Black's Guide "is essentially a voluntary reporting of building space, vacant space, and asking rents, by address and owner"[29]. Because the Black's Guide data collection is passive (it relies on voluntary reporting), Urbanomics reported that Black’s Guide tends to focus "largely on recent construction, though some counties -- such as Essex -- undoubtedly include pre-1980 stock"[30]. Therefore the Guide likely substantially under-reports the supply of existing rental office space located in older buildings. In addition to this bias to towards newly constructed buildings, the Black’s Guide, by definition, only reports space that is for rent and excludes office space that is sold. This ommission of owner-occupied office space is significant for two reasons. First, realtors contacted by OSP report that approximately 25% of all office space in the State is owner occupied. Second, sometimes entire indutries change tenure. For example, Sitar and Company reported that in the last few years the State's Pharmaceutical

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[29]Memorandum from Regina Armstrong to Bob Kull and Jim Reilly, titled Office space data, dated 7/07/93.
[30]Ibid.

companies changed their tenure relationship from primarily leasing office space to now owning approximately 90% of their office space.

Yet another problem with the Black's Guide data is that it sometimes includes hotel, and retail space as well as sometimes including speculative space (space not yet built) in its municipal office space inventories. Urbanomic attempted to cull the data to exclude reports of speculative space and non-office type space such as hotels and retail space, however it is likely that some "non-office" space was included.

The final technical problem with the Black's Guide data is that it was collected for only 1990. This means that all analysis is restricted to cross sectional examination. A more comprehensive approach would be to collect inventories for several years (a time series). The advantage of the time series is that it could reveal trends about office space occupation.

(2) Employment

The New Jersey Department of Labor provided information which identified the number of employees in 1990, by type of employment, for each of the 567 municipalities in the State. The source of the data was the ES 202 records, through which an employer forwards to the State various taxes relating to his employees, such as unemployment insurance. Three sets of data were provided to OSP: one for private sector employment; the second reporting local and state government employment; and, the final reporting federal employment. For each data set the total number of employees in each of 99 Standard Industrial Code (SIC) categories is identified.

While the ES 202 data in generally very uniform, it has certain limitations. It excludes all self employed persons. It does not report agricultural employees. Finally, while payment of the taxes is not voluntary, providing all of the information about the location of the employment is voluntary. This means that a company with two factories might report all employment as if it all worked at the factory that contains the headquarters operation. Another locational problem is that NJ DOL only has the business address of the firm. Since municipal boundaries and Zip codes are not contiguous, occasional municipal locational errors can result when a business is located in a zip code covering more than one municipality. While the accuracy of the data has not been tested, it is commonly thought that the ES 202 data is locationally accurate for at least 90% of all employment.

(3) Changes to the Office Space and Employment data sets

Prior to the statistical analysis, both the office space inventory and the employment data were altered or generalized to accommodate the demands of forecast modeling. First, the inventory of available (for rent) office space for each municipality was subtracted from the total municipal supply of office space to identify the total occupied office space. This was performed given the assumption that existing office employment (1990) was most likely located in occupied (1990) office space.

Second, municipal employment (reported as the number of employees in each of 99 SIC's) was re-aggregated into nine larger employment groups as displayed in the following table. (Employment in SIC's 1 through 19[31] was not included in the study). Although it was recognized that individual SIC's might be more highly correlated to Office space utilization, the grouping was done so that less detailed alternative employment forecasts could be utilized in the model and so that fewer, more robust, variables would be identified in the regression and cluster analysis[32].

Table 9
SIC'S IN EACH EMPLOYMENT GROUP

SIC's	EMPLOYMENT GROUPS
1 through 19	Not included in the study
20 through 29	SIC 2x (manufacturing group 1)
30 through 39	SIC 3x (manufacturing group 2)
40 through 49	SIC 4x (transportation/utilities/communication
50,51	SIC 5w (wholesale trades)
52 through 59	SIC 5r (retail trades)
60 through 69	SIC 6x (F.I.R.E.)
70 through 79	SIC 7x (services group 1)
80 through 89	SIC 8x (service group 2)
90 through 99	SIC 9x (public employment)

(4) The Statistical Relationship between Employment and Office Space.

Two statistical examinations were performed. First, a proceedure called 'cluster analysis' was performed to learn if there was a difference in the mix of employment at the municipal scale. The second examination consisted of several regression analysis comparing both the municipal and the county inventories of occupied office space to employment by type and other variables to learn if certain types of employment were related to office space use.

(a) Cluster Analysis

Cluster analysis was done to learn of the similarities or dissimilarities between the municipalities, based solely on employment, by general group. Five clusters, or groups, of municipalities were discovered and are displayed in the following table. Also displayed are the cluster centers for each SIC group and a chart showing each group's employment by type as a percentage of total municipal employment.

[31]These categories include agricultural, mining and construction trades jobs.
[32]As the number of variables is increased, the fit of any regression equation is improved. However, these added variables may not be very explanatory. Similarly, as the number of variables, or attributes, in a cluster analysis is increased the resulting groupings may be meaningless, as individual municipal employment differences become dominant in the clustering.

TABLE 10
NUMBER OF MUNICIPALITIES IN EACH CLUSTER

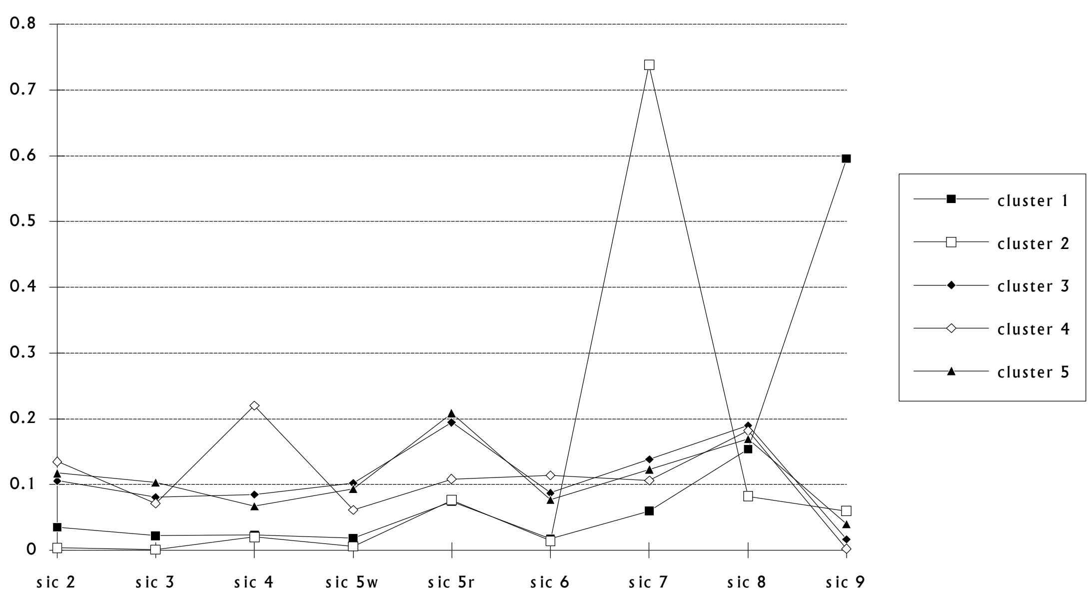
Cluster	Municipalities
1	8
2	1
3	28
4	1
5	435

TABLE 11
CLUSTER CENTERS POINTS BY EMPLOYMENT TYPE

Cluster	SIC 2x	SIC 3x	SIC 4x	SIC 5w	SIC 5r
1	298	191	198	153	629
2	241	42	1225	333	4675
3	3318	2533	2667	3209	6100
4	15277	8071	24932	6909	12268
5	442.	388	251	352	785

Cluster	SIC 6x	SIC 7x	SIC 8x	SIC 9x
1	147	508	1311	5061
2	867	45330	5020	3673
3	2736	4347	5949	515
4	12944	12006	20547	206
5	290	463	639	150

Chart 8
PERCENTAGE OF EMPLOYMENT BY TYPE FOR EACH CLUSTER



Based on the preceding tables and chart, each of the clusters can be characterized in the following manner. Cluster 1, which consists of eight municipalities[33], is most prominently categorized by its large presence of public sector employment (SIC 9x) and corresponding low representation by other employment groups. Cluster 2, which consists of Atlantic City, is most notable in its disproportionate representation in SIC 7x, which includes hotels and casinos. Cluster 3 contains 28 municipalities[34], including such diverse places as Camden City, Jersey City, Elizabeth, Paterson, Princeton Township and Cherry Hill. While these places might differ in wealth and amenity, they share the common characteristics of containing generally diverse and relatively large employment concentrations. Cluster 4, Newark, dominates several employment types simply because of the large number of jobs located in the City and the dominance of SIC group 4. Finally, in cluster 5 there are 435 other New Jersey municipalities which had smallish, relatively homogenous mixes of employment types.

The important finding from this analysis was that the vast majority of New Jersey municipalities were relatively homogenous with respect to the presence of the major employment groups. The exceptions being Newark, Atlantic City and the eight municipalities in cluster1. (This finding is most clearly seen in the diagram of percent of employment by type, which shows the similarity of clusters 3 and 5). This finding suggests that if correlations between occupied office space and employment by type can be established, that these relationships should apply in almost all municipalities in the State.

(b) Regression Analysis

The office demand equation, presented in the preceding section, in part argues that the demand for new office space is a function of employment in the future. However, while some workers in nearly all types of employment spend at least part of their day in an office-like environment, in certain types of employment most of the workers perform their duties in a office-like setting. The assumption behind the regression analysis then is that these office reliant types of employment can be identified by examining existing employment and its correlation with existing occupied office space.

Regressions were performed using the Urbanomics office space data and the NJ DOL ES 202 data using two geographic scales (one analysis performed with municipal scale data and the second performed for data aggregated to county scale) and using two office data sets (the first using all 473 municipalities included in the 16 county Black's guide survey and the second using only the 220 municipalities reported to have occupied office space). A total of 11 independent variables were compared to the dependent variables office space. The following table lists these variables.

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[33]Metuchen, Long Branch, Sea Bright, Madison Borough, North Haledon Borough, Montgomery Township, Blairstown, and Frenchtown.

[34]Clifton, Dover, Parsippany, Morristown, Woodbridge, Piscataway, New Brunswick, Hackensack, Paramus, Camden, Cherry Hill, Pennsauken, Fairfield Township, Livingstone, West Orange, Jersey City, Secaucus, Hamilton Township, Lawrence Township, Princeton Township, Trenton, East Brunswick, Edison, Paterson, Wayne, Franklin, Elizabeth, and Union Township.

TABLE 12
VARIABLES USED IN THE REGRESSION ANALYSIS

Dependent Variable	**Description**
space	occuppied office space
Independent Variables	
pop1990	total population in forecast year
pden1990	population in forecast year / area in square miles
sic2x	total employment in forecast year, SIC's 20 through 29
sic3x	total employment in forecast year, SIC's 30 through 39
sic4x	total employment in forecast year, SIC's 40 through 49
sic5w	total employment in forecast year, SIC's 50 and 51
sic5r	total employment in forecast year, SIC's 52 through 59
sic6x	total employment in forecast year, SIC's 60 through 69
sic7x	total employment in forecast year, SIC's 70 through 79
sic8x	total employment in forecast year, SIC's 80 through 89
sic9x	total employment in forecast year, SIC's 90 through 99

The following table displays the results from the four regressions. It will be noted that transformation of the variables to logarithmic expressions was required to produce valid analysis in the municipal analysis. These transformed values also proved to be quite robust, since they closely approximated several resistant measures of means.

Table 13
REGRESSION COEFFICIENTS FOR EACH OF FOUR DATA SETS

	sic5w	**sic6x**	**sic7x**	**sic8x**	**sic9x**	**pden**	**constant**	**Adj R Square**
cntyall		581.06			-198.87		67663	.87952
cspaconly		466.46					94415	.85446
	log(sic5w)	**log(sic6x)**	**log(sic7x)**	**log(sic8x)**	**log(sic9x)**	**log(pden)**	**constant**	
muniall	.24	.605	.259	-.168		-.182	7.55	.55286
mspaconly	.316	.597				-.188	7.91	.52104

cntyall = county scale regression that uses the sum of all municipal employment, population and office space for the 16 counties inclused in Black’s Guide.
cspaconly = county scale regression using only the data for the 219 municipalities with complete data sets.
muniall = regression of all 473 municipalities included in the Urbanomics survey.
mspaconly = municipal regressions using only the data for the 219 municipalities with complete data sets.

Several interesting findings can be derived from the preceding table. First, employment in SIC's 60 through 69 (Finance, Insurance and Real Estate) appear to be those employment types most highly correlated with office space, regardless of the scale of the analysis or the data set used in the analysis. At the municipal scale, other important type of employment are wholesale trades and services.

For one of the county analysis (cntyall), a negative correlation appears between office space and public employment. In both of the municipal scale regressions a negative correlation exists between office space and population density. To some degree, these negative correlations might be related, since the older urbanized counties have the highest levels of public employment and the municipalities with the highest population densities. It also is possible that the older more urbanized counties have less new office space than do the more rural counties, or it could mean that the older more urbanized counties have a larger inventory of existing buildings available to accommodate office demand. Finally, these negative relationships might be reflecting a market demand for more campus-like, more "prestigious" locations for office development: sites which are more difficult to develop in more urbanized areas.

(5) Regression Analysis - Validity Testing

Three different types of validity testing were performed on the resulting regression equations. First, the regression results were compared with statistical findings reported by the California Public Utility Commission. Second, the results of the regression were compared to the knowledgeable comments provided by various Realtors interviewed for this study. Finally, the equations were used to re-estimate the 1990 supply of office space.

The California Energy Commission was created in 1975 as " a compromise between interests seeking a one stop certification of power plants, and a state role promoting energy consumption"[35]. The demand forecasts produced by the Commission staff are used to specify power demand needs (especially capital improvements, such as plants) and "to integrate conservation policy with power plant siting approval"[36]. Because staff forecasts directly regulate the electrical power industry in the State, these forecasts have been developed with great skill and are constantly being refined.

Part of the California model estimates future office space using statistical correlations between space and employment by type. To develop its analysis, the Commission has carefully collected data about employment and the existing supply of office space. The base year for the California data is 1964, when an actual 100% physical inventory of all non-residential space in the state appears to have been conducted. Since that time, this base inventory then has been updated using information from Dodge Digest (the same type of information collected by Urbanomics and used in this study), by monitoring building permit data, and by conducting periodic physical surveys to test the data. The following types of employment are reported by the California Energy commission to be correlated with office space utilization.

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[35]California Energy Commission. California Energy Demand: 1993-2013, Electrical Demand Forecasting Methods. June 1993 page 1-1.
[36]Ibid. pg. 1-1.

TABLE 14
EMPLOYMENT TYPE CORRELATED WITH OFFICE SPACE IN CALIFORNIA

Business Activity	SIC code	Dodge Code
Administration	91-96 (minus 921,922)	005-007
Financial	60-61	005-007
Real Estate, Legal	62-67 (minus 6561, 6563), 81	005-007
Public Offices	91-96 (minus 9222, 966)	100
Medical Offices	801-804	005, 007
Veterinary Offices	074	005, 007
Agricultural Offices	076, 078	005-007
Other Office	7300 (minus 7384,7390), 972	005-007

source: Table 3-9, Staff's Building type, SIC Code, & Dodge Code, California Energy Demand 1993-2013, page 3-31.

The California findings agree very nicely with the results of the OSP regression analysis. The importance of the employment groups sic6x and sic7x is displayed in both analyses. It also is clear why the employment group sic6x is the prominent explanatory variable, given that the California results demonstrate in detail the wide spread correlation between almost all types of employment in this group and office space.

The use of office space by firms in the FIRE and services categories also was reinforced during interviews with Realtors. Interviews were conducted with Realtors from the following firms: Sitar & Company, Bender and Company, Cushman and Wakefield and Jackson and Cross.

However, neither the California data nor the Realtor interviews supported the importance of wholesale trades as a major variable related to office need. Because of this lack of corroboration, regressions were performed on 12 counties, where sufficient municipal data existed to perform the analysis[37]. It was discovered that employment in the Sic5w group was significant in Bergen and Essex counties only. However, employment in this group continued to be significant, statewide, when the municipal scale data was used in the regression analysis.

To further test the validity of the variables, additional statistical tests were conducted to determine the Collinearity of the Sic5w employment with employment in group Sic 6x and with the variable 'logden', which expresses the population density of the municipality. When independent variables are collinear, they tend to supply the same information because the variables themselves are related. All the tests were performed from data taken from the spaconly file, which only contained the 219 municipalities for which complete sets of data had been collected. The analysis also was performed using the logarithmic expressions of the employment and density numbers to be consistent with the regression analysis.

In the first test, the tolerance and variance inflation factors (VIF) for each variables were examined. In the second test, the eigenvalues and condition indexes were examined.

[37]Analysis was performed for Bergen, Camden, Essex, Hudson, Mercer, Middlesex, Monmouth, Morris, Ocean, Passaic, Somerset, and Union counties. Insufficient data prevented the analysis of Atlantic and Burlington counties.

Table 15

COLLINEARITY TEST - SPACONLY DATA SET

TEST 1 - TOLERANCE AND VARIANCE INFLATION FACTOR ANALYSIS

Variable	SE Beta	Tolerance	VIF	T	Sig T
LOGDEN	.050824	.905262	1.105	-3.357	.0009
LOG5W	.060261	.643926	1.553	4.613	.0000
LOG6X	.060704	.634564	1.576	8.864	.0000
(Constant)				16.387	.0000

TEST 2 - VARIANCE ANALYSIS

Number	Eigenvalue	Cond	Variance Proportions			
		Index	Constant	LOG5W	LOG6X	LOGDEN
1	3.92859	1.000	.00113	.00220	.00215	.00117
2	.03917	10.015	.10515	.24194	.19769	.12474
3	.02204	13.350	.00111	.75215	.79978	.00003
4	.01020	19.628	.89261	.00371	.00039	.87406

The results of the tolerance and VIF examination appear to be inconclusive. Although the tolerance decreases and the VIF's increase for the variables log5w and log6x, the shift in both of these test values is insufficient to clearly demonstrate collinearity. More striking results are produced in the second series of tests. The condition indexes for lines 2 through 4 are somewhat high, suggesting that small changes in the values of any of these independent variables might produce large (and unwarranted) changes in the resulting estimate of office space need. However, the conclusive proof that these variables are highly interrelated (near-dependency) is demonstrated by the high variance proportions exhibited in line 3 between log5w and log6x. This finding supports the conclusion that the best model of office space need, for this set of municipal data, is employment in the Sic 6x group, together with the constant. This is not to say that Sic 5w employment does not significantly contribute to the demand for office space in the State, especially in Bergen and Essex counties, however it does suggest that a model equation using only Sic 6x and the constant would be just as reliable as an equation using all of the significant variables.

The same tests of collinearity were performed on the data set using all 473 municipalities. Surprisingly different results were produced. All of the variables appear to be valid despite the relatively high condition indices evident in lines 5 and 6. None of the variance proportions for any of the eigenvalues displays near-dependency.

Table 16

COLLINEARITY DIAGNOSTICS

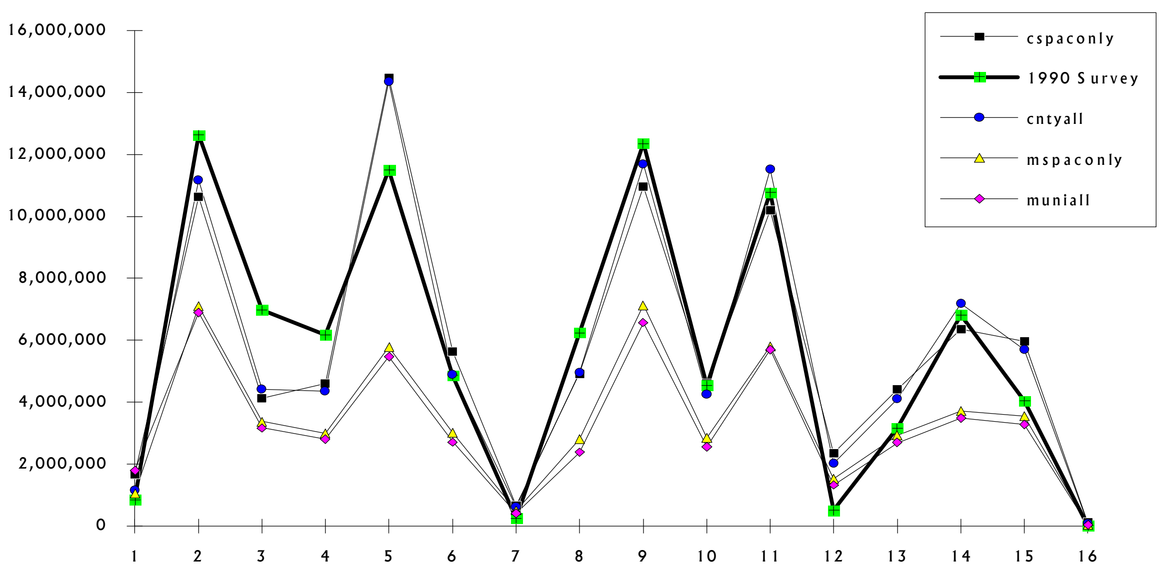
Variable	SE Beta	Tolerance	VIF	T	Sig T
LOG8X	.067301	.500663	1.997	-2.397	.0174
LOGDEN	.051150	.866768	1.154	-3.278	.0012
LOG5W	.067165	.502694	1.989	3.160	.0018
LOG6X	.075795	.394739	2.533	7.078	.0000
LOG7X	.084055	.320970	3.116	2.361	.0191
(Constant)				15.456	.0000

Number	Eigenval	Cond Index	Variance Proportions Constant	LOGDEN	LOG5W	LOG6X	LOG7X	LOG8X
1	5.88423	1.000	.00047	.00050	.00077	.00060	.00030	.00096
2	.04644	11.257	.10201	.09994	.00310	.05439	.00099	.23622
3	.03319	13.315	.01252	.03709	.46165	.00533	.00590	.32362
4	.01757	18.299	.00363	.00309	.28615	.74517	.00194	.35505
5	.01032	23.874	.60292	.80921	.03944	.05654	.10540	.00479
6	.00825	26.710	.27845	.05017	.20890	.13797	.88547	.07936

The final test of validity was performed by using the regression equations to backcast the 1990 inventory of Office Space. This test is most interesting, since it not only demonstrates the ability of the equations to replicate known data (and more importantly data from which the equations were derived), but it demonstrates the problem of scale for regression equations. The following graph displays the actual 1990 supply of office space for each of 16 counties and then the resulting estimate of office space produced by each of the four equations.

Chart 9

COMPARISON OF MODEL AND ACTUAL OFFICE SPACE INVENTORIES



It can be seen that the equations based on municipal data consistently produce estimates of county office space that are lower than the actual supply. The equations based on county scale data produce estimates that are much closer to the actual inventory. Partially, the inability of the municipal-based equations to estimate county numbers is the result of the scale of the equation itself. The municipal based equations produce good estimates of county totals only when the sum of the municipal equations in a county are totaled. If the municipal equation is directly used to estimate county office space, the result is likely to be inaccurately low.

(6) Identification of Model Equations

Despite the inability of the municipal-based equations to replicate county office space inventories, all four regression equations discussed in the preceding sections have been incorporated into the model. The principal variables and coefficients in these equations are significant, and pattern those identified in the county-scale equations. Proof of the validity of this is the fact that the municipal-based space estimates increase and decrease in harmony with the actual space supply; only the quantity of space is under-estimated. The municipal based equations are used to simulate a future where much less office space is needed than is currently required for the same number of office related jobs. The use of the county based equations simulates a future where the same number of office related jobs requires approximately the same amount of office space as was the case in 1990.

Two additional equation also have been included. The negative coefficient associated with SIC 9x employment, included in the cntyall model, has been reduced to produce a new model. This new model then tends to increase the estimate of office space in the older more urbanized counties of the state, where it is assumed higher than average public employment is located. The second new model uses the muniall equation, but includes factors for each county that are equal to the difference between the muniall 1990 estimate of office space and the amount of office space identified by Urbanomics. The following table displays the name of each model equation and the associated data set from which it was derived.

1. **Cntyall** $\underset{cnty}{\bullet}\ sic6x * 581.063445 \cdot \underset{cnty}{\bullet}\ sic9x * \cdot 198.869211 \cdot 67663$

2. **Cspaconly** $\underset{cnty}{\bullet}\ sic6x * 466.458507 \cdot 94415.5$

3. **Muniall**

$$\exp\left(\ln\left(\sum_{cnty} sic6x\right)\times .604694 + \ln\left(\sum_{cnty} sic5w\right)\times .244492 + \ln(pden)\times -.182179 + \ln\left(\sum_{cnty} sic8x\right)\times -.168478 + \ln\left(\sum_{cnty} sic7x\right)\times .259833 + 7.552882\right)$$

4. **Mspaconly**

$$\exp\left(\ln\left(\sum_{cnty} sic6x\right)\times .596706 + \ln\left(\sum_{cnty} sic5w\right)\times .315858 + \ln(pden)\times -.187855 + 7.913439\right)$$

5. **Lessen9** (cntyall adjusted) $\sum_{cnty}(sic6x)\times 581.063445 + \sum_{cnty}(sic9x)\times -160 + 67663$

6. **Muniadj90** muniall + (actual 90 office space - muniall 90 forecast)

where:

cnty = any county
ln = natural logarithm

exp = *e* raised to the power of a number

As noted in the preceding section, the municipal-based equations have varying degrees of problems associated with their use. These problems are especially acute with the equation based on the data set that only included municipalities for which office space was noted. The use of any of the three model equations, derived from county scale data, is preferred.

b) Office Space Per Employee

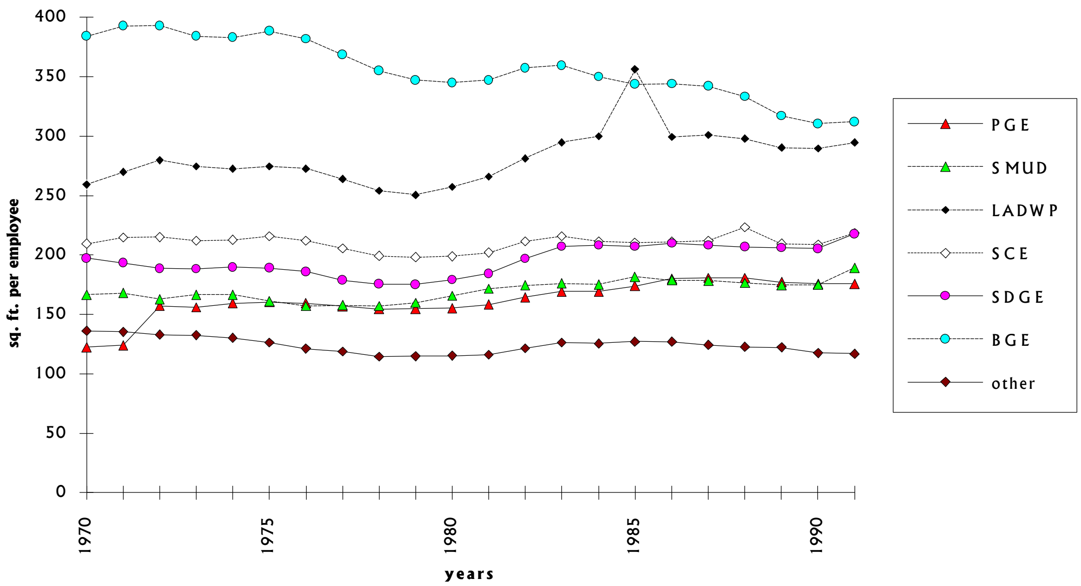
Estimates of the amount of office space used by the average office-based employee were collected from published sources, from opinions offered by experts, and from historic trend data for California, contributed by the California Energy Commission.

Two published estimates of office space per employee were identified during the course of this study. In February of 1992, the Center for Urban Policy Research at Rutgers University published a table as part of the work undertaken to evaluate the Interim State Development and Redevelopment Plan. Although CUPR published the table, they identified the source of the information as the Building Owners and Managers Association, the Institute for Real Estate Management, and the Urban Land Institute. The CUPR estimate is 285 square feet of gross space for each employee. The second published source is the Electrical Power Research Institute's 1988 study by Regional Economic Research Incorporated. EPRI's estimate was 350 square feet per employee, with a more detailed estimate of 319 square feet for employees located in small office buildings and 369 square feet for employees located in large office buildings.

In addition to the published estimates, the Director of Research at the Building Owners and Managers Association (BOMA) in Chicago stated that the space per employee had decreased from an old "rule" of 250 square feet to a current demand of approximately 200 square feet per employees. However, BOMA’s International (Washington) market expert contended that the demand for space had increased to over 300 square feet per employee.

As previously mentioned in this report, the California Energy Commission has excellent information describing the supply of Office space in California. The Commission's records were begun in 1964, with a complete physical inventory of all non-residential space in the State and have been updated and verified since that time. Total office space information for the years 1970 through 1990, for the seven electric power Service areas of the state, was supplied to OSP by the commission staff. In addition, the Energy Commission's data also identified the total number of Office workers, by year, for each of the seven service areas. This information is displayed in the following graph.

Chart 10
ANNUAL AVERAGE SQUARE FOOTAGE PER EMPLOYEE
CALIFORNIA ENERGY SERVICE AREAS 1970 TO 1991



The results displayed in the graphed California data are quite interesting. First, it appears that two space groups exist in California; one where the office space per employee has exceeded 250 square feet since 1970 and the rest of the state, where smaller space allocations are more the norm. In the Burbank, Glenside and Pasadena service area (BGP) and the Los Angeles Department of Water and Power service area (LADWP), space allocations for employees drifted , one increasing and the other decreasing, until today they appear to be converging towards 300 to 325 square feet per employee. In all remaining five service areas the allocation ranges from about 150 to about 225 square feet per employee and appear to have been fairly stable since 1970. The California data has been used in the model to justify the inclusion of two estimates of square footage per employee; a low estimate of 200 square feet per employee; and, a high estimate of 300 square feet per employee.

Finally, Realtors and trade industry groups, most notably BOMA, were asked for their opinions of whether space allocations for office employees would change or remain constant, and for their assessment of why any changes might occur. For once unanimous, the realty personnel agreed that less space likely would be allocated for office workers of the future. Several causes for this downsizing were identified. It was contended that increasing percentages of the office workforce are being assigned to modular workspaces, as opposed to being assigned separate office spaces. Another trend is for businesses to lease only office space on a permanent basis and to lease meeting rooms or conference rooms on an as-needed basis, either from common rooms available in their office building or from hotels. Another trend is for businesses only to lease space for the number of employees expected on a given day. This concept has two forms. The first form contends that more employees will perform at least some of their work at home, probably using computers or terminals. The second form argues that certain types of businesses have employees routinely "in the field" either selling products, visiting clients or working at client locations. Since either of these situations mean that on any given day likely only part of the firm's total employment would be located in its offices, less total space would have to be rented. To accommodate the work-at-homers or the travelers when they did come to the office, common office space would be made available provided the visiting person made reservations to visit his home office (hence the name "hotelling" for this use of common office space by multiple employees).

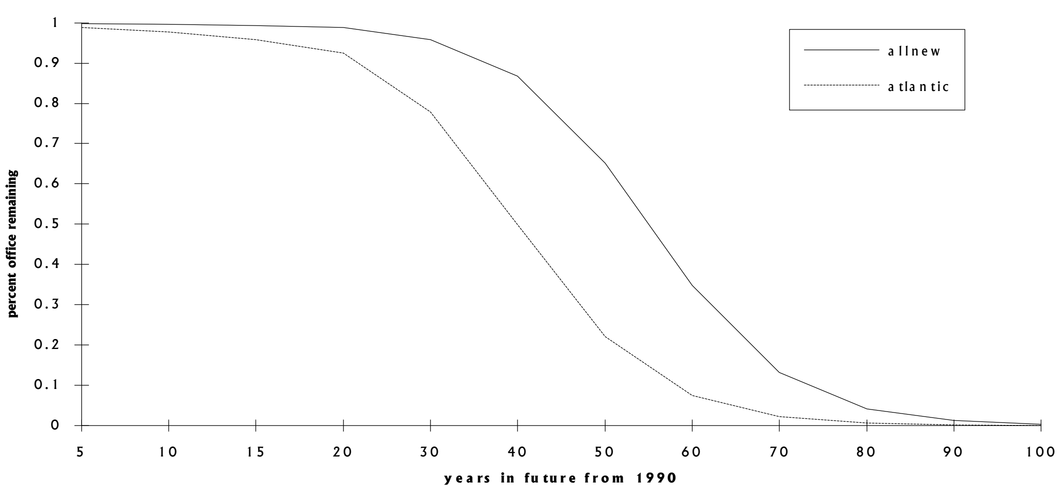
c) Office Decay Model

Office buildings do not last forever. Some buildings are destroyed by fires every year. However, most building fulfill their purpose until such time as they no longer represent the highest investment for the building site. In this sense, the inventory of office buildings tends to be reduced annually; first to a small degree by calamity, then to an increasing degree as the economic vitality of the investment declines.

To mimic this decline in the stock of office buildings, the OSP model uses an equation developed by the National Laboratory at Oak Ridge. Two variables are user determined as input into the model. The first variable (mnlife) determines the mean economic life of an office building. The second variable (stckage) estimates the mean age of the office buildings. Since the building inventory in any county includes a mix of new and old buildings the resulting decay formula has to be adjusted to take the base year mean age into account. The following graph displays the equation's effect of decreasing the inventory of office space in Atlantic County given a mean building life of 55 years and an average building age of 25 years compared to a county where the mean life was 55 years but all of the building were new.

Chart 11

OFFICE DECAY DIAGRAM AND EQUATION



$$1-\left(\frac{1}{\left(1+\exp\left(\frac{6.91-6.912}{mnlife*\left(t+stckage\right)}\right)\right)}\right)$$

where:

t = years from base year to forecast year
mnlife = mean life of a office buildings
stckage = estimated base year average age of office building

The mean age of the office space stock was estimated by using the mean age of the housing stock, as reported in the 1990 Census. It was assumed that the office stock lagged the development of houses by 10 years in all counties except for Hudson. In Hudson County, the age of the office stock was made 20 years younger that the housing stock to reflect the large number of new office buildings that have recently been developed, especially along the waterfront. The following table displays the assumed age of the office stock for each of the counties.

Table 17
ASSUMED AVERAGE AGE FOR OFFICE INVENTORY

County	Mean Building Age
Atlantic	15
Bergen	26
Burlington	14
Camden	21
Cumberland	15
Cape May	21
Essex	31
Gloucester	15
Hudson	29
Hunterdon	13
Mercer	23
Middlesex	17
Monmouth	17
Morris	18
Ocean	8
Passaic	28
Salem	23
Somerset	14
Sussex	14
Union	29
Warren	22

d) Natural Vacancy

The term natural vacancy does not suggest that it is natural for some space in all buildings to be vacant. Natural vacancy is an economic term which tries to identify the demand supply equilibrium point beyond which any new demand results in the construction of new space. As such, the idea of natural vacancy is part of the larger rent-adjustment process.

During times of low demand and high inventories of available space, owners tend to discount prices to generate cash flow, especially if the vacancy rate is in excess of the owners break-even. Currently, such a low demand and high inventory condition exists in New Jersey. Realtors stated that the decline of prices for Class A space has severely impacted the occupancy of older buildings. As demand and supply level out, rental prices rise. If demand exceeds supply owners charge premium prices for office space, and since the demand is heavy and the potential for profit appears to be good, new construction is initiated.

In the office assignment model, the concept of natural vacancy is used as a constant. As the demand for space in a region increases, as a result of increased employment, it is assigned to the available regional inventory of vacant space. As long as the demand for space can be fitted into the region's residual (decayed) space, then no new construction is assumed in the program. However, once the demand is in excess of the residual inventory, less the amount of the space deemed naturally vacant, the program will try to build new office space and assign the office building footprint to available land.

Surprisingly little has been published to document the natural vacancy rate. The mean values that have been documented in the research literature vary from a low of 3.91% to a high of 8.59%. Natural vacancy rates included in the model range from 4% to 14%, and are user selected.

e) Incorporating the Office Space Equations into the PED model

The PED model assigns employment growth projections to municipalities using three main subroutines. In all three subroutine, only future changes to the base year employment were assigned. The programming assumed that the same number of employees would be present in any municipality as in the base year and that this base year employment would be adjusted (up or down) by the employment projection. In the first subroutine, regional growth (future employment - base year employment) is assigned to any municipality using one of a variety of mathematical formulas; the program's selections of specific formula is predicated on the rate of employment change in that municipality during a user selected historic period[38]. This first subroutine is referred to as the "unfitted" assignment program. The second assignment subroutine tests the "fit" of the unfitted assignment by checking to make sure that sufficient available developable land exists in municipalities to accommodate the unfitted growth. If sufficient land is not available, the program reassigns this excess growth to other municipalities in the region. Because the effect of the unfitted subroutine combined with this second assignment subroutine is to simulate the growth pattern likely produced by an "unregulated" market, this second subroutine is referred to as the "Trend" assignment program. The third assignment program, described in detail in this report, simulates the re-distributive effect that the State Development and Redevelopment Plan would have on Trend. This final subroutine is referred to as the "plan" assignment program.

The new Office space fitting model constitutes a fourth employment fitting subroutine; one that precedes the other three fitting models. Therefore, the first employment which is assigned from exogenous county (or regional) projection is employment assigned to the residual municipal 1990 supplies of office space. Then remaining county (or regional) employment is assigned to municipalities using the "Unfitted", the "Trendfit" and, as directed, the "Planfit" subroutines.

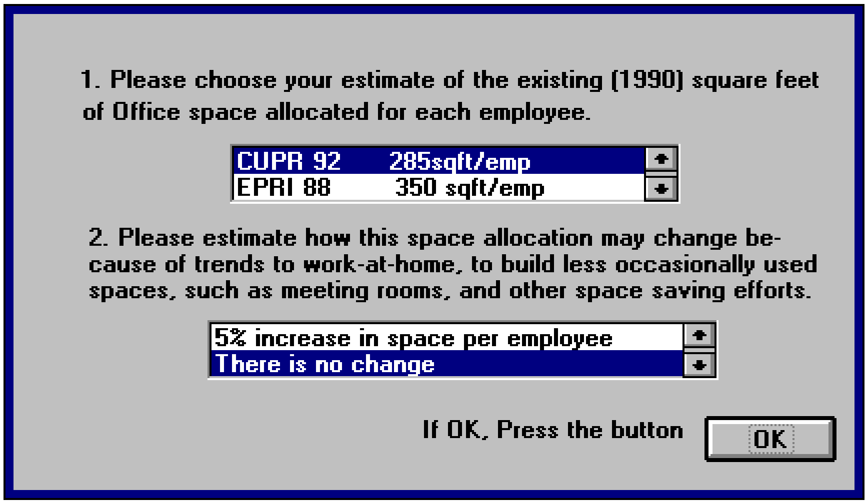
The Office space fitting model, like the rest of the PED model was written in Excel using: three worksheets, one of which is only used to store program variables while the others contain data and equations; two input screen; and, two command "macros", which contains the programming to run the subroutines and to link the subroutines to the rest of the PED model.

At the beginning of the PED model one of the "macros" allows the program user to select values, from a list of program alternatives. The resulting user selections are then stored in a worksheet for use later in the PED model. The following shows the input screens created by the

[38]See: Reilly, James. Demographic and Economic Forecasts, Task 4 - Traffic Zone Projection Method Recommendations, Trenton, NJ. Office of State Planning. April 1993.

"macro" and then lists the variables, from which the user can select, that are then stored in the worksheet *offvars.xls*.

Screen 2
OFFICE SPACE INPUT SCREEN 1



Question 1 alternatives

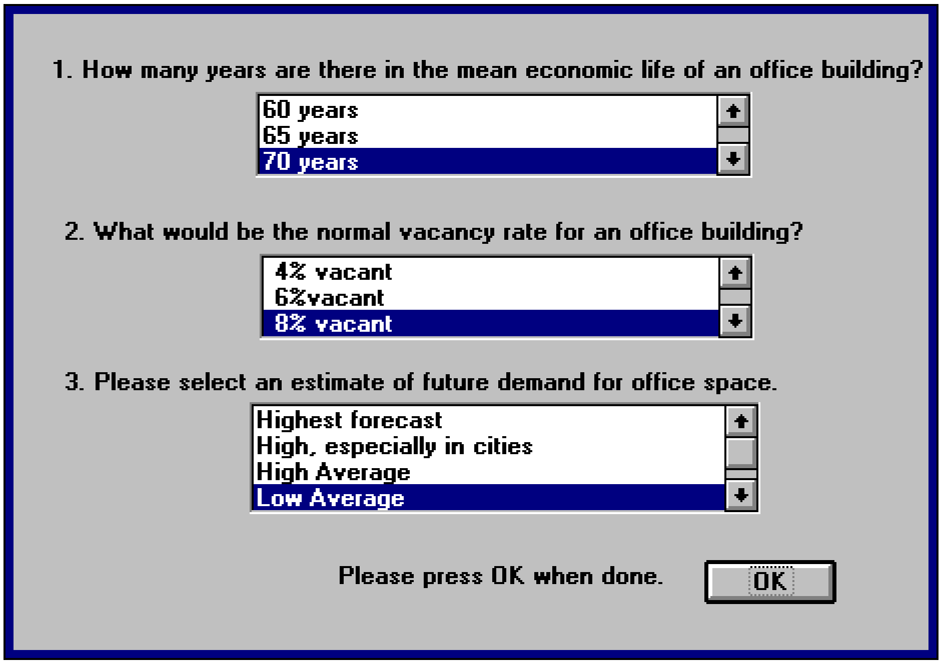
CUPR 92	285 sq. ft.
EPRI 88	350 sq. ft.
PUC CA/BOMA low	200 sq. ft.
PUC CA/BOMA high	300 sq., ft.
OSP 93 est.	240 sq. ft.

Question 2 alternatives

5% increase in space per employee
There is no change
5% decrease in space per employee
10% decrease in space per employee

Screen 3

OFFICE SPACE INPUT SCREEN 2



Question 1 alternatives

- 40 years
- 45 years
- 50 years
- 55 years
- 60 years
- 65 years
- 70 years
- 75 years
- 80 years

Question 2 alternatives (natural vacancy)

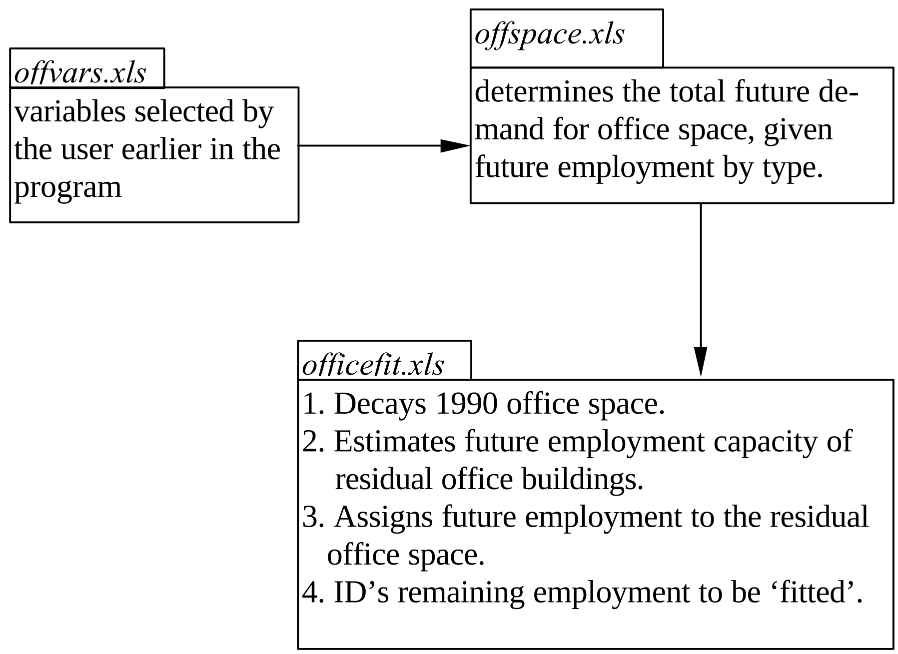
- 4% vacant
- 6% vacant
- 8% vacant
- 10% vacant
- 12% vacant
- 14% vacant

Question 3 alternatives

- Highest Forecast
- High, especially in cities
- High Average
- Low Average
- Low Forecast
- Very Conservative

Later in the PED model, the user selected variables are re-opened and the second half of the office fitting program activated. The following diagram identifies the program's worksheets and lists the products calculated in each.

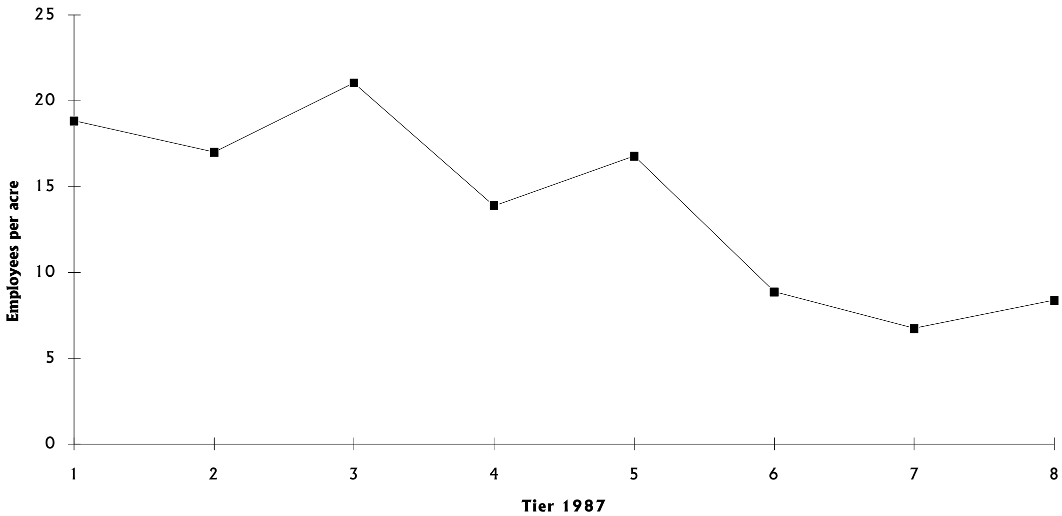
Diagram 2
THE OFFICE FITTING PROGRAM



2. Alternative Employment Densities

To test the 'fit' of jobs, initially assigned jobs are multiplied by municipal specific employment densities to determine the land footprint required for the job growth. This municipal specific job density was developed by OSP using 1986 Aerial photoquads and 1985 ES 202 municipal employment. (A more complete description of this process is provided earlier in this report). The following graph displays the average density for all municipalities grouped according to the 1987 Tier system, which included 8 planning areas.

Chart 12
AVERAGE EMPLOYMENT DENSITY



where:

tier 1 = redeveloping cities and suburbs
tier 2 = stable cities and suburbs
tier 3 = suburban and rural towns
tier 4 = suburbanizing areas
tier 5 = exurban reserve
tier 6 = agricultural areas
tier 7 = environmentally sensitive agricultural areas
tier 8 = environmentally sensitive areas

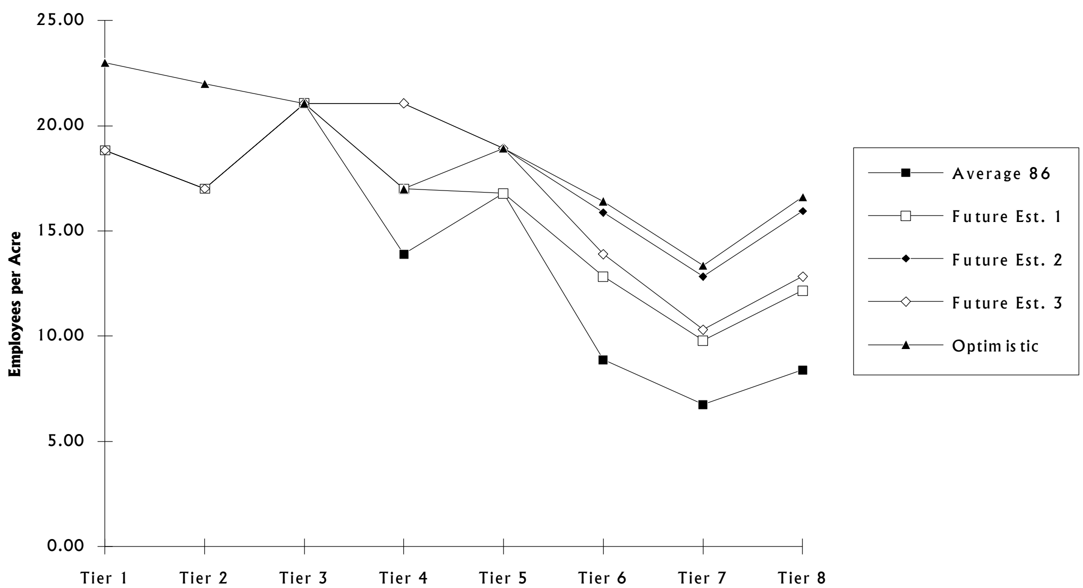
a) Developing Alternative Densities

As displayed in the graph, densities tend to decrease as tier numbers increase. The highest employment densities are found in redeveloping cities and suburbs, suburban and rural towns and in Tier 5, where much of the new office based employment has located in the last twenty years. The graph demonstrates that the use of differing employment densities is appropriate. However, the graph suggests that densities can be expected to change in response to the amount of development pressure applied to these areas (i.e. densities will increase in the more rural parts of the State as employment grows). To more closely model this density change alternative employment densities were developed by adjusting the average 1986 densities. In addition, an optimistic density was prepared which shows the employment density increasing in the urban tiers and matching the Future 1 alternative in Tiers 4 through 8. This density is intended for use only with the Urbanomics Optimistic forecasts. The following table and graph display the density alternatives.

Table 18
DENSITY ALTERNATIVES

	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5	Tier 6	Tier 7	Tier 8
Average 86	18.85	17.01	21.06	13.90	16.79	8.87	6.74	8.38
Future Est. 1	18.85	17.01	21.06	17.00	16.79	12.83	9.79	12.17
Future Est. 2	18.85	17.01	21.06	21.06	18.92	15.88	12.83	15.96
Future Est. 3	18.85	17.01	21.06	21.06	18.92	13.90	10.32	12.83
Optimistic	23.00	22.00	21.06	17.00	16.79	12.83	9.79	12.17

Chart 13
EMPLOYMENT DENSITY ALTERNATIVES

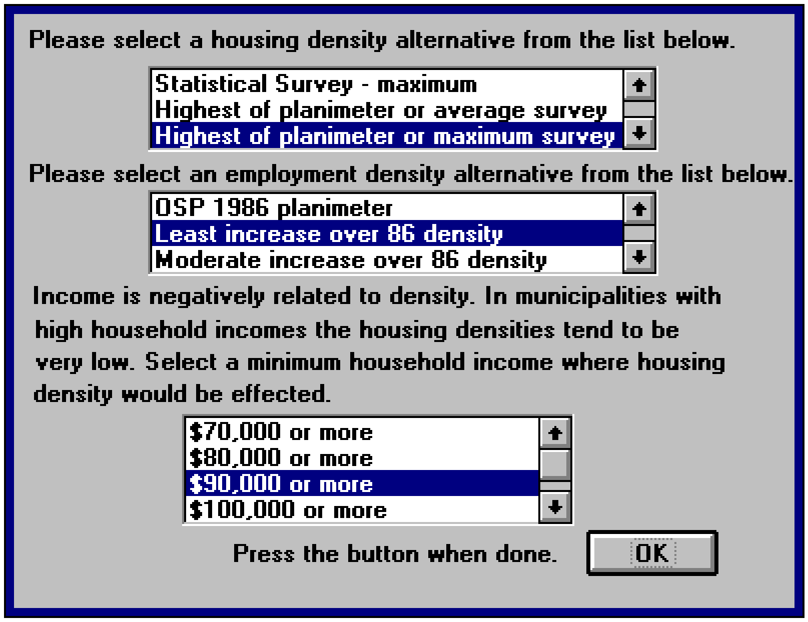


b) Incorporating the Employment Densities into the PED

Model users can select the employment density that they feel is most appropriate. At the beginning of the program, the following 'dialog' screen prompts the model user to select the alternative they prefer. The user choice is stored as a variable in the model. Later when the program is fitting jobs to available land in municipalities, the user selected alternative is used.

Screen 4

EMPLOYMENT DENSITY INPUT SCREEN



Dialog label	Density Alternative
OSP 1986 planimeter	Unique Density for each municipality
Least increase over 86 density	Future 1 Density by Tier identity
Moderate increase over 86 density	Future 3 Density by Tier identity
Highest increase over 86 density	Future 2 Density by Tier identity
Optimistic Scenario	Optimistic Density by Tier identity

D. DEVELOPMENT OF THE PLAN SCENARIO

The State Development and Redevelopment Plan contains a complex series of policies and strategies which intend to improve the quality of life for all state residents. Simulation of all the Plan's recommendations would be impossible. The simulation prepared for the PED model focuses on the Plan's policies that would redistribute population and employment from the pattern that would result from a continuation of trend development practices. In particular, the PED simulation focuses on the pivotal SDRP concepts of capacity based growth allocations and the Resource Planning and Management Structure(RPMS).

The resource planning and management structure proposes that all land be grouped into of one of five planning area categories, intended to represent the "unique qualities and conditions that exist in different areas of the State" (SPC 1992 pg. 101). Policy 17 of the Plan states that "Planning Areas are delineated on the basis of infrastructure and natural systems and do not necessarily correspond to municipal or county boundaries" (SPC 1992 pg. 28). Each Planning area has a separate policy objectives intended to guide growth. In addition, the resource planning and management structure proposes that growth be allocated into a hierarchy of centers. The hierarchy (size) of centers is Urban Center, Regional Center, Town, Village, Hamlet. The compact form of the centers would serve to organize growth in beneficial ways.

Under the concept of capacity based growth, new growth would be assigned "by using systems capacity information as a basis for guiding growth to and among Planning Areas and Centers in a manner that makes the most efficient use of these systems and protects their capacities" (SPC 1992, pg. 17). The Plan defines these systems as: infrastructure; natural resources; fiscal; economic and social.

However, even with this simplified SDRP based assignment concept, several problems remain. First, there are very few designated Centers, other than the eight Urban centers listed in the Plan document. Second, the concept of capacity based growth ultimately involves a delicate balance between infrastructure improvements, fiscal costs and resource management. Finally, it is likely that much of the SDRP's effect will occur at a sub-municipal level; a scale below the level of design of the PED, which was intended to redistribute growth between municipalities. It therefore was necessary to make several type of generalization in the simulation model.

1. Identifying Centers and Their Capacities

Appendix C of the SDRP lists existing towns, existing and planned regional centers, village and hamlets that were identified during the Cross Acceptance process as likely candidates for center designation. These places were used in the simulation.

Growth capacities for each type of center were taken from Appendix 5, Center Planning Guidelines, of the OSP publication The Centers Designation Process (OSP 1993). These guidelines can be found in Appendix D of this report. Growth limits for Towns, Regional

Centers, Villages and Hamlets were identified by interpreting these guidelines. Where the guidelines specified variable ratios or densities, a user input screen was developed to allow the model user to change these variables within allowed ranges.

Base line population and employment for each existing identified center was estimated by the OSP Area Planning Manager in charge of the region in which the identified center was located. Development of these base line numbers was frequently performed with the cooperation of county and municipal planners. A vacant land inventory for each center also was developed by the Area Planning Managers, which identified both the acres available for development by Planning Area in each identified center.

2. Simulating Infrastructure Capacity

The provision of sewerage service was used to simulate infrastructure capacity. OSP has obtained extensive records from DEPE, which identify the number of persons in each municipality who receive sewer collection services and the number of persons in the future who are scheduled to receive service, according to the utility's Annual EPA mandated Needs Survey. For purposes of the Plan simulation, it is assumed that sewer service is sufficient to accommodate the growth capacity of the Center is provided to all the Centers that are required to be provided with public sewerage. It also is assumed that the cost of any additional sewer service to Centers is justified by other benefits to be derived from the Plan. The forecasted population that is sewered is assumed to be located in accordance with the SDRP's intent.

Population assigned in excess of a municipality's projected sewer service capacity is identified as growth that may be reallocated by the Plan simulation. To determine the percentage of future population that is not served, the assigned Trend population is compared to the municipality's forecasted served population. In areas of the State that do not have substantial sewer service forecasted, but are assigned large growth allocations under Trend, the simulation uses a stochastic statistical model to re-estimate the percentage of future population that would be served with sewers. The following diagram displays this model's ability to replicate sewer provision.

Chart 14

PERCENT OF POPULATION ON COLLECTORS AS A FUNCTION OF LOG(POPULATION DENSITY)

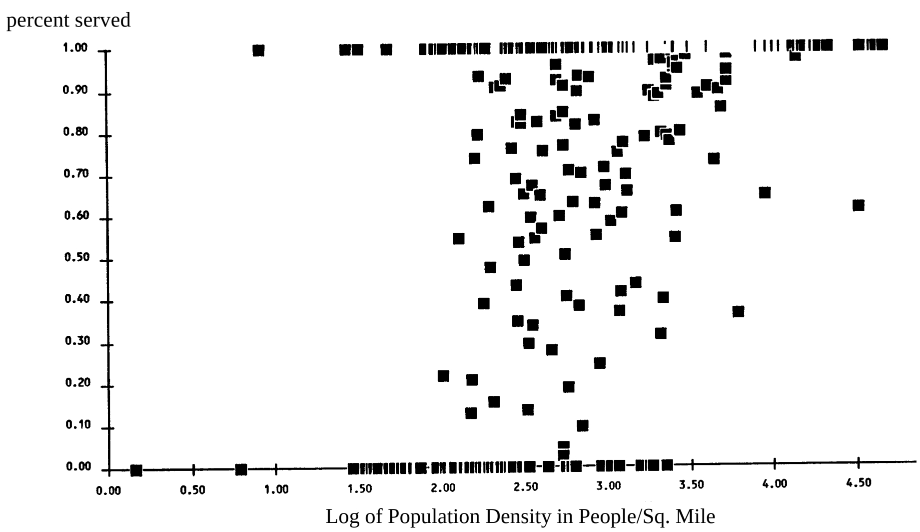
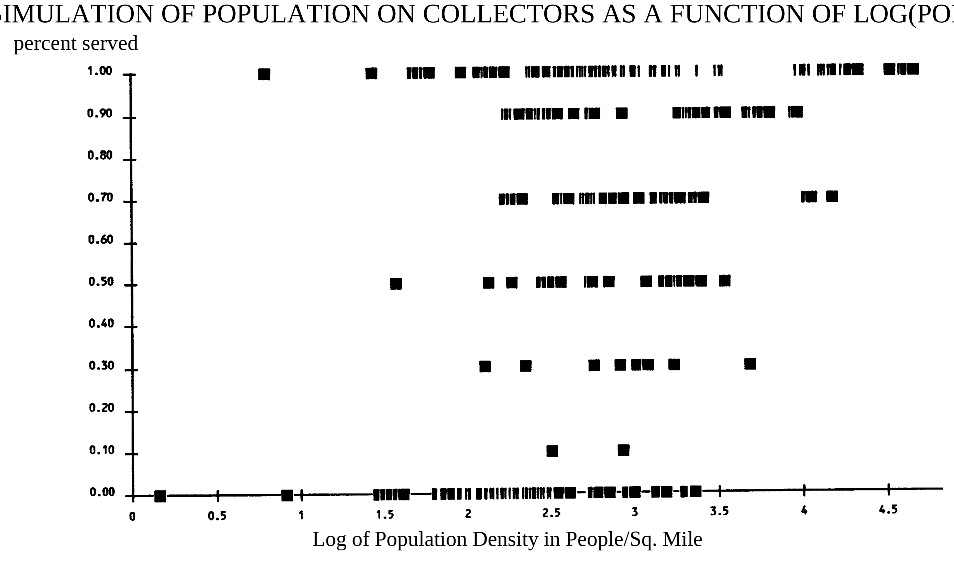


Chart 16

OSP SIMULATION OF POPULATION ON COLLECTORS AS A FUNCTION OF LOG(POPULATION DENSITY)



3. Simulating the Plan

The Plan simulation begins after the Trend allocation program has concluded. This was done to ensure that the effect of Plan was to modify Trend growth patterns and not to completely redirect Trend growth. The Plan simulation intends to redirect Trend growth, in areas not served with sewer systems, to Centers located in Planning Areas designated for growth. Growth assigned to a region or county by the Trend simulation is reallocated in the same county or region by Plan. From a regional perspective, Plan does not reallocate growth between regions. The effect of Plan is to reallocate growth between and within municipalities in the same region.

The maximum extent to which Plan allocates growth within a region is determined by several factors in the program. First, the program prompts the user to estimate the maximum amount of non-sewered growth that would be available for redistribution. Second, the effect of this redistribution is limited to the available capacity of centers in the region. In determining this redistributive capacity, all Trend allocated growth to these centers is continued at Trend densities. Plan redistributed growth is "fitted" only to remaining available developable land and this growth is then fitted at user-selected Plan densities.

Between the two concepts of Capacity based planning and RPMS very definite growth assignment rules can be identified. Policy 18 of the State Plan states that "Where a municipality or county has more than one Planning Area within its jurisdiction, growth should be guided to Centers in Planning Areas of lowest numerical value..."(SPC 1992, pg. 28). Again on page 23 of the SDRP, Statewide Policy 5 of the section Centers and Capacity-based Planning states

"Planning for infrastructure investment among Centers requires that projected growth be allocated among the Centers. The following steps, in the order presented, should be used as a guide in this allocation process:

(1) allocate growth to existing Centers with sufficient existing or planned system capacities;

(2) allocate any remaining growth to existing Centers where infrastructure can be most cost-effectively expanded and extended and where market demands justify the need;

(3) allocate any remaining growth to planned (new) Centers where new infrastructure, sufficient to maintain system capacities, should be built or paid for by the private sector; and,

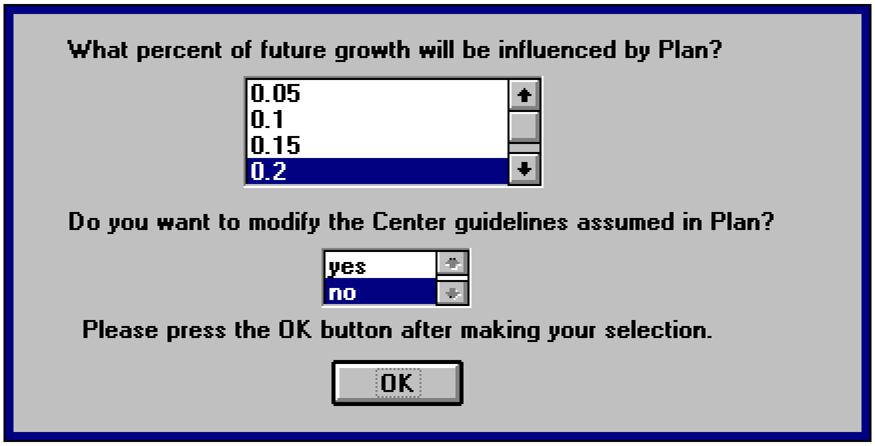
(4) allocate any remaining growth to planned (new) centers where it is in the public interest to build new infrastructure through joint public/private investment."

The Plan simulation tries to rigidly adheres to this concepts. Once the amount of regional growth available for redistribution is identified, it is assigned to all existing Centers in Planning Area one. If residual growth is available it then is allocated to any new Centers that might have been designated and that are located in Planning Area 1. Assignments then are made to existing Centers and then New Centers in each planning area in numeric sequence beginning with Planning Area two and concluding with Planning Area 5.

As with most other program subroutines in the PED, the Plan simulation executes in two parts. The first part prompts the model user to select plan variables. The user selections are then stored for use in the second part of the model. The following shows the user input screen used in this first part of the Plan simulation and identifies the user options. It should be noted that the user is not allowed to alter the capacities of the centers from the input screen.

Screen 5

PLAN VARIABLE INPUT SCREEN



Percent of Growth influenced by the Plan

5%
10%
15%
20%
25%
30%
40%
50%
60%
70%
80%
90%
100%

Table 19

PLAN VARIABLES TABLE

	PA1	PA2	PA3	PA4A	PA4B	PA5
jduUC	10	8	6	6	4	4
jduER	5	4	3	2	2	2
jduTN	4	4	3	2	1	1
jduV	2	2	2	1	0.5	0.5
jduH	1	1	0.5	0.5	0.25	0.25
duacreUC	20	10	8	6	4	4
duacreER	20	20	8	6	4	4
duacreTN	12	8	6	5	4	3
duacreV	12	10	4	3	3	3
duacreH	5	4	3	2	2	2

capER	15000
capTN	4000
capV	2000
capH	100

note:

jdu values for UR (Urban Centers) do not have limits.

jdu values for ER (Regional Centers) must be in the range 2 < 5

jdu values for TN (towns) must be in the range 1 < 4

jdu values for V (Villages) must be in the range .5 < 2

jdu values for H (Hamlets) must be in the range .25 < 1

duacreUC values do not have limits

duacreER values must be in the range 3 < 20

duacreTN values must be in the range 3 < 12

duacreV values must be in the range > 3

duacreH values must be in the range > 2

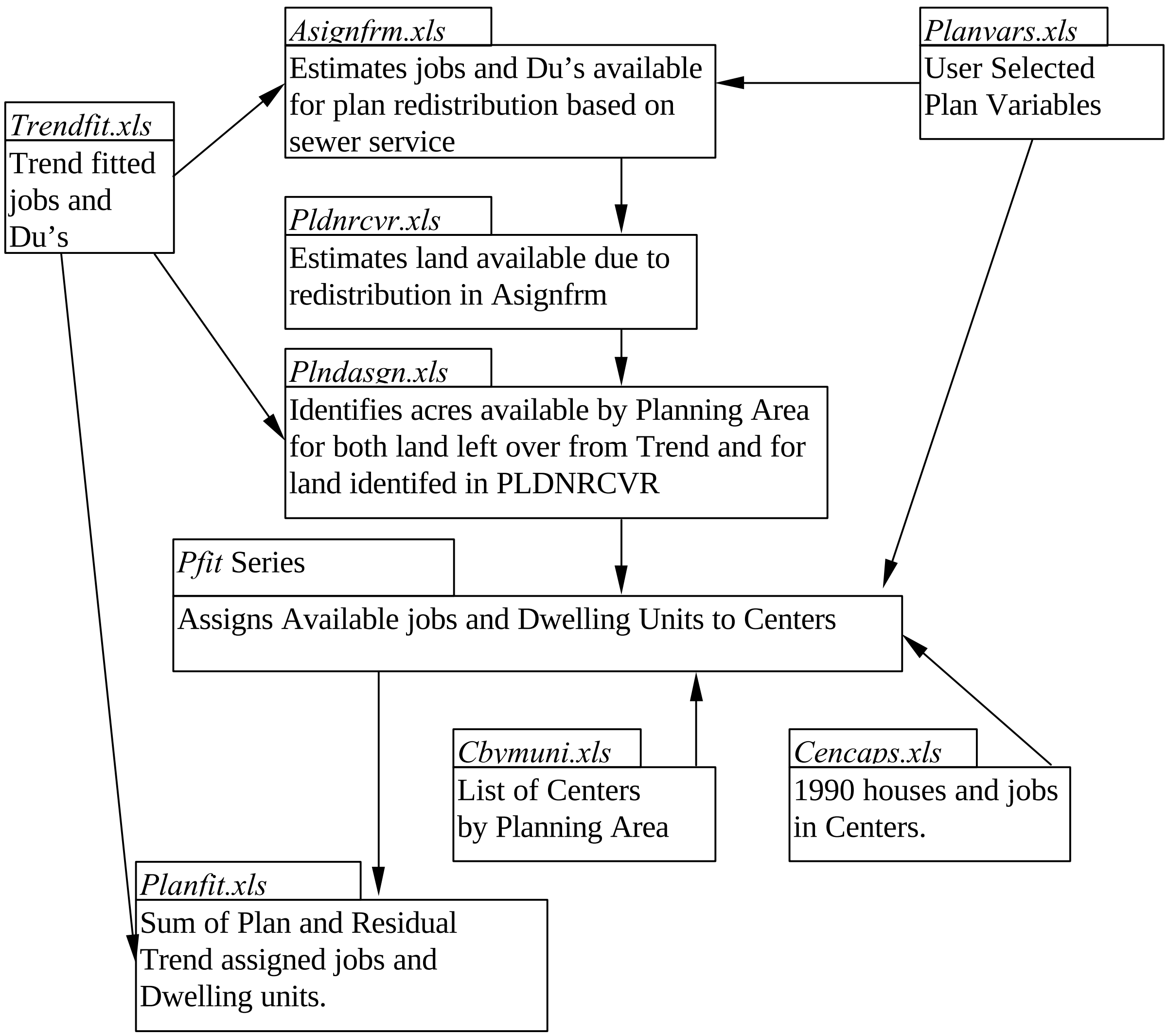
where:

jdu = ratio of jobs to dwelling units
duacre = dwelling units to the acre
UC = Urban Center
ER = Regional Center
TN = Town Center
V = Village Center
H = Hamlet Center
Cap = maximum number of dwelling units

The second part of the program executes after the Trend assignment subroutine has run. In this part of the Plan simulation The Trend municipal growth assignments, in a region or county (as specified by the user elsewhere in the PED), are redistributed to reflect Plan policies. The results of the Plan simulation are new municipal estimates of jobs and houses.

Diagram 3

THE PLAN SIMULATION MODEL



The results of Plan sometimes are difficult to realize from the results of the PED model. The model produces municipal based estimates of future population and jobs. Some of the Plan's effect is to redistribute growth within a municipality, without making a substantive change in the number of jobs and houses, when comparing Plan to Trend. Secondly, the Plan simulation performed for NJ DOT assumed that the maximum effect of Plan through out the forecast period would be limited to a maximum redistribution of 20% of new growth assigned by Trend to areas without sewers. The selection of 20% does not establish a desired goal, but rather a minimum conservative estimate of voluntary compliance.

E. OTHER ADJUSTMENTS

1. 1990 Base

The original PED model used 1980 as the base year for all statistics and assignment activities. During the course of this work effort, the base year for most equations and assignment programs was changed to 1990. Exceptions to the 1990 base are:

- The equation in the income subroutine that estimates welfare income. This equation was not updated due to lack of information.
- The equation in the income subroutine that estimates household income distributions by demographic characteristics. The data in the 1990 Census file STF2 was not available to OSP.
- The OSP land availability inventory was not updated from 1986 to 1990.

2. Land Available Inventories

In addition to the OSP 1986 land available inventory, the Rutgers University land available inventory (1993) was added to the model. This inventory was prepared from satellite imagery, which then was adjusted to exclude such atmospheric problems as cloud cover. The principal advantage of the Rutger coverage is that it is State-wide, while the OSP 1986 mapping does include Pinelands, CAFRA or HMDC lands. The disadvantage of the coverage is that it is not aware of land development constraints for available land, such as wetlands, park land etc.

A third available land inventory was prepared by OSP by combining the 1986 OSP data with the Rutgers converage. In this hybrid coverage, the Rutgers data was used to complete the OSP 1986 Coverage.

Another improvement to the entire series of available land inventories was the addition of under permanent farmland preservation easement. Under the terms of this easement program of the New Jersey State Agriculture Development Committee the development rights of farmland are purchased by the State. Farmers benefit from reduced taxes on the land. Farmers continue to own the land and to have the right to use the land for farming practices. Land in this program has been deleted for the available land inventory.

The New Jersey Department of Agriculture also has an eight year easement program. However farms covered under this program can be developed with some administrative costs. These farms have not been excluded for the available land inventory.

3. Wage Alternatives

The Income modeling subroutine estimates future wages in part by multiplying the number of jobs by type by forecasts of future wages for the same type of employment. The existing wage table in the model was taken from 1982 BEA estimates of future New Jersey wages. This wage table has been expanded to include 1985 BEA and 1990 BEA wage forecasts for New Jersey and 1990 WEFA wage forecasts for New Jersey.

V. THE VALUE OF STATISTICAL MODELING

It is very much the fashion to dismiss statistical analysis, and especially statistical modeling, as unreliable or inaccurate. While OSP has not made a study of the causes of this phenomenon, the validity of the models should be considered in light of the following.

First, most people do not understand the limitation of statistical estimates. The result of a carefully produced statistical equation is a best mathematically-based guess of a phenomenon. For example, it would be co-incidental if a municipal population or employment forecast for the future proved to be correct to the exact number of people and jobs. The statistical result might be somewhat higher or lower than actual result. For example, if your toss a coin into the air 20 times and try to predict the number of "heads", a statistical model would predict 10 or 11 since the statistical methods forecast the *most likely* result, while the actual result of a single experiment might be 8, or 12 or some other number. The statistical methods used in this report (and commonly used in science) assume that data is normally distributed. Even after using mathematical transformations to improve the shape of the data, it is very rare when all the data is shaped so continuously. Therefore, the statistical result needs to be recognized as the most likely number, and given a large number of experiments (such as 567 municipalities), the results from a statistical model,overall, will be very reliable. However, the use of these statistical methods also means that a few municipal forecasts will not be very close to the actual result, even when one is backcasting. This effect can be minimized by using other statistical methods, such as cluster analysis, to reorganize the data into subsets that are similar to one another. But the fact remains that some municipal forecasts will not be close to the actual result. The importance of knowing that this is the case is two fold: first, it emphasizes the need for forecast users to be flexible about corrective suggestions, provided there are substantive reasons provided to justify the correction; and, second, this knowledge demonstrates that a few missed forecasts do not invalidate the majority of the forecasts. This knowledge argues that the baby should not be thrown out with the bath water.

Second, there is an assumption that human activities, such as land development, are so complicated and decisions involve so many variables weighted in virtually unique ways, that there is no order to the system. In effect, the argument is that people, because of their free will, are not predictable in the same way that natural processes are predictable. The truth of the matter is that nature is not very predictable either. Just think about the accuracy of weather forecasting. Even in more established disciplines, such as physics, there exists an uncertainty element which requires the use of statistics. Does this then mean that, like weather forecasting models, all statistical models are inherently uncertain? Not really, since statistical analysis is very widely used with reliability in such widely ranging disciplines as the development of new medications and the telephone system. The truth likely is that the more that is known about the underlying causes of change, the more reliable the statistical model will be in projecting future conditions.

APPENDIX A

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APPENDIX B

OFFICE SPACE INVENTORY FOR COUNTIES FROM BLACK'S GUIDE

APPENDIX C

DESIGNATED AND IDENTIFIED CENTERS
FROM:
COMMUNITIES OF PLACE
THE NEW JERSEY STATE DEVELOPMENT AND REDEVELOPMENT PLAN

APPENDIX D

CENTER CORE CHARACTERISTICS
FROM:
THE CENTER DESIGNATION PROCESS